Long-Term Manuring: What Happens When Application Ceases?

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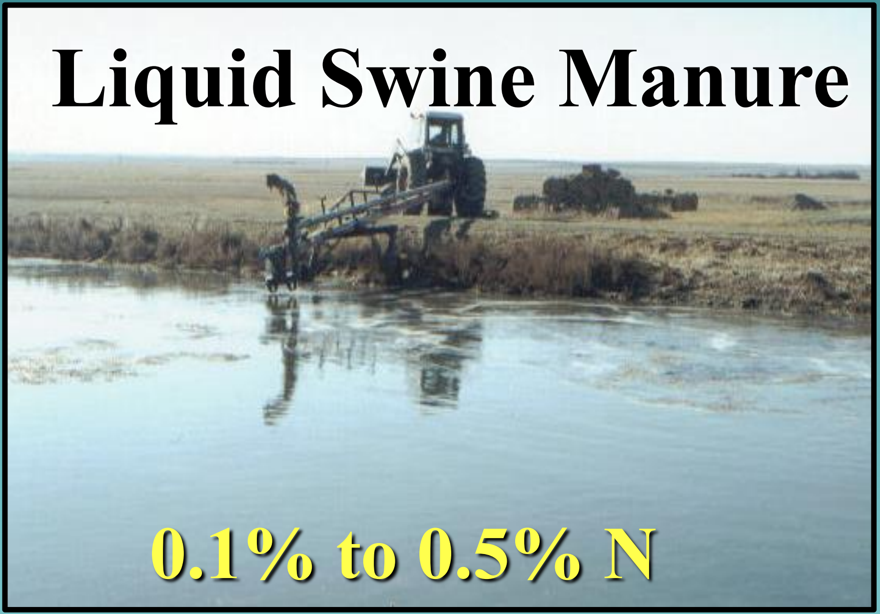
Role of Manure as a Source of Plant Nutrients

- **A resource:** contains plant nutrients and O.M.
- **A challenge:** variable, dilute, expensive to move long distances.
- **The goal:** using best management practices to maximize agronomic benefit and minimize impact on the environment.



Much of N is **immediately available** ammonium

Much of N is **slowly available** organic forms

- **Variable** Must test to know what is in it.
- **Restrictive** May not have the balance of nutrients needed. May need to supplement with commercial fertilizer.

How to Manage Manure?

- ✓ **<u>As a Fertilizer</u>**
  - ✓Know What's In It
  - ✓Know How It Behaves

***Liquid Effluents**: High availability of nutrient in year of application, not much organic matter. > 90 % water; ~< 2 % solid material

***Solid Manures**: Slow availability of nutrients, lots of organic matter, long-term soil builder. ~50% water; 50% solid material

Manure applied at appropriate rate and method of application is sustainable and economical

Nutrient Management Planning:
A Balancing Act

- ✓ Select rate of applied manure nutrient that matches crop demand and nutrient removal over time.
- ✓Determine appropriate rate using manure testing, soil testing.
- ✓ Use application technologies that get the manure in the ground.
- ✓Ensure proper ratio of available nutrients in soil following manure application.

Placement:

Cumulative N recovery

Swine ~ 100 lbs N/ac/yr **injected**	43%
Swine~ 100 lbs N/ac/yr **broadcast/incorp.**	31%

Drag Hose

Low Disturbance Injection

Liquid Hog Manure Injection

- Liquid hog manure is applied via a direct injection system.
  - Agronomical and environmental advantages of LHM direct injection well documented (Mooleki et al., 2002).

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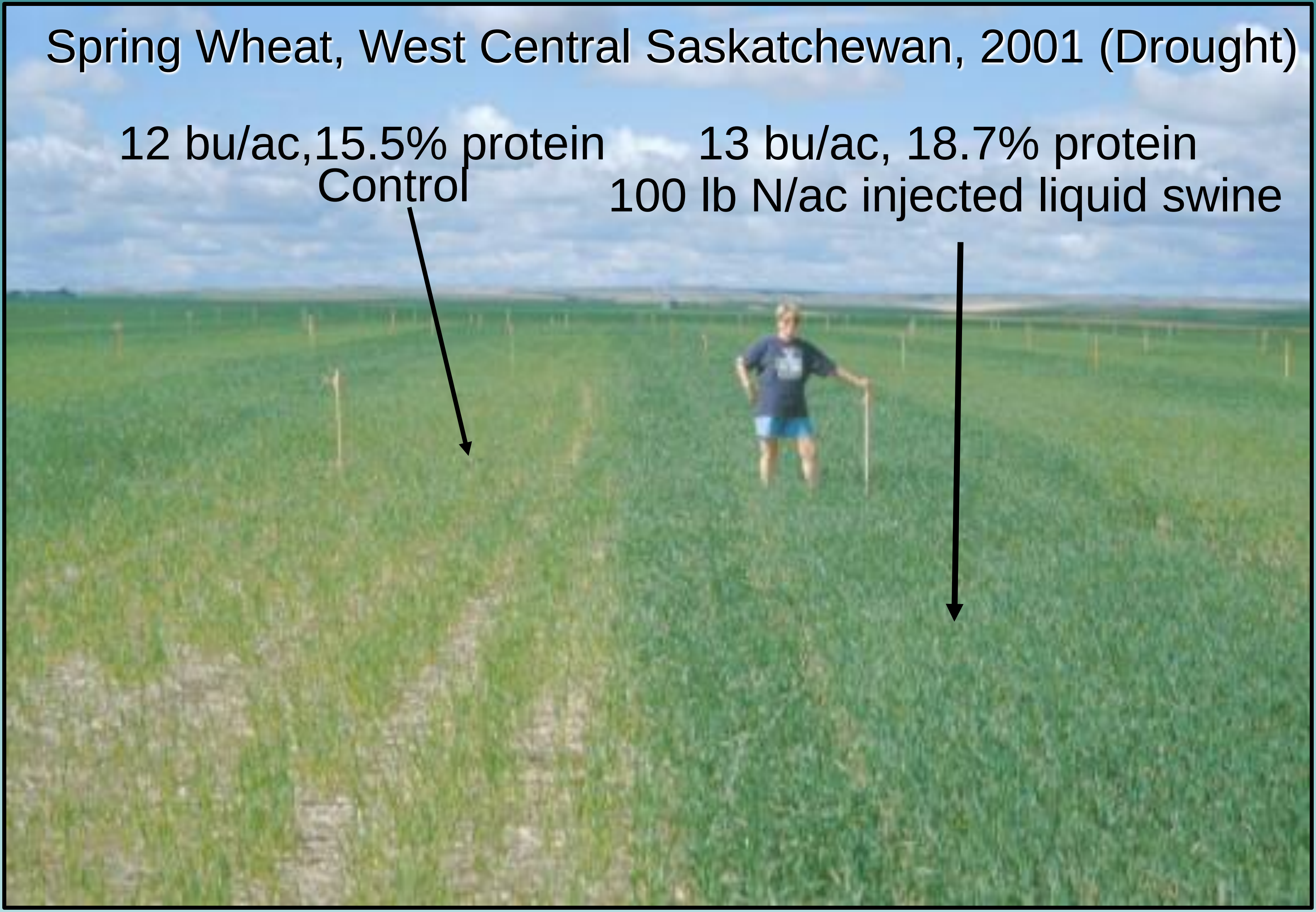
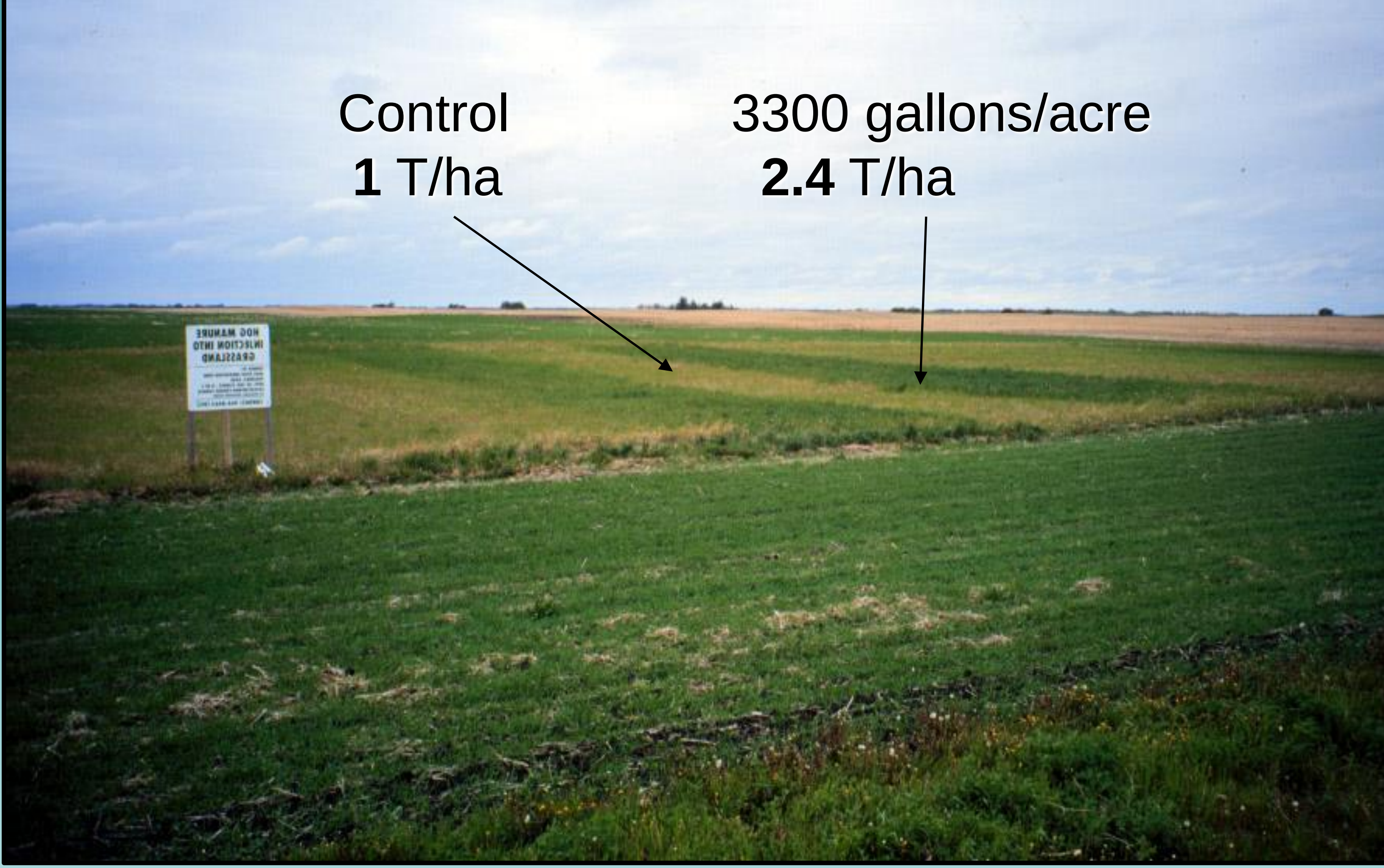
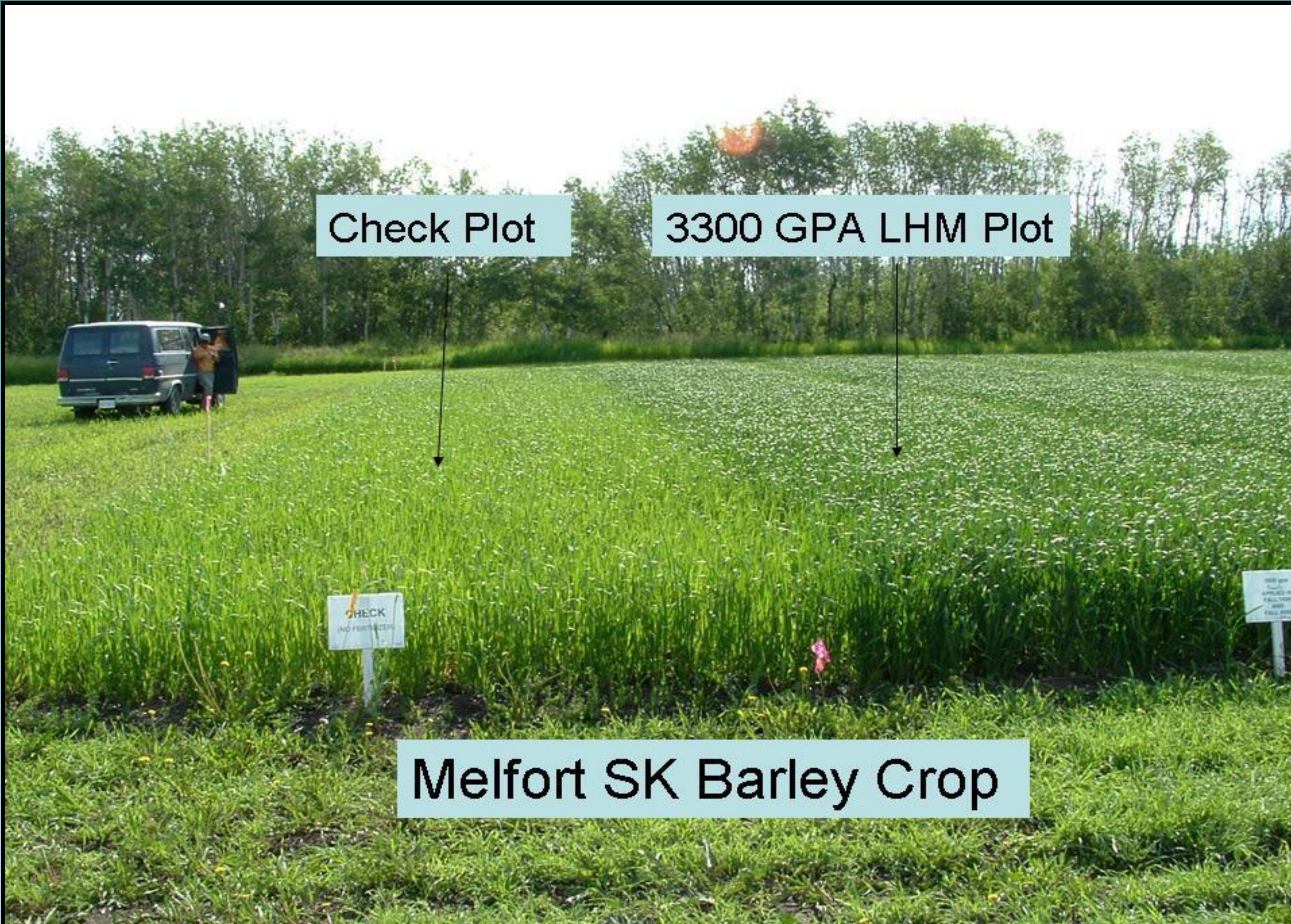

Spring Wheat, West Central Saskatchewan, 2001 (Drought)
12 bu/ac,15.5% protein
Control
13 bu/ac, 18.7% protein
100 lb N/ac injected liquid swine

Injected Liquid Swine Manure into Crested Wheat




Check Plot
3300 GPA LHM Plot
Melfort SK Barley Crop

SCM Direct Injection Equipment

Solid Manure Injection

- **Three years of data (07-09) from study at Humboldt showed <u>no large differences</u> in yield, N recovery between surface, B&I, and injected SCM.**
- **Solid manure used had <u>low ammonium content</u>: mainly organic N. As such, limited potential for volatile gaseous ammonia losses.**
- **Injection did not reduce P transport in snowmelt water.**

Thin Section Slab Collection and Simulated Snowmelt Runoff

Altering C.V. of SCM Application

- ***Traditional equipment used to apply Solid Cattle Manure (SCM) often results in <u>non-uniform distribution</u>.***

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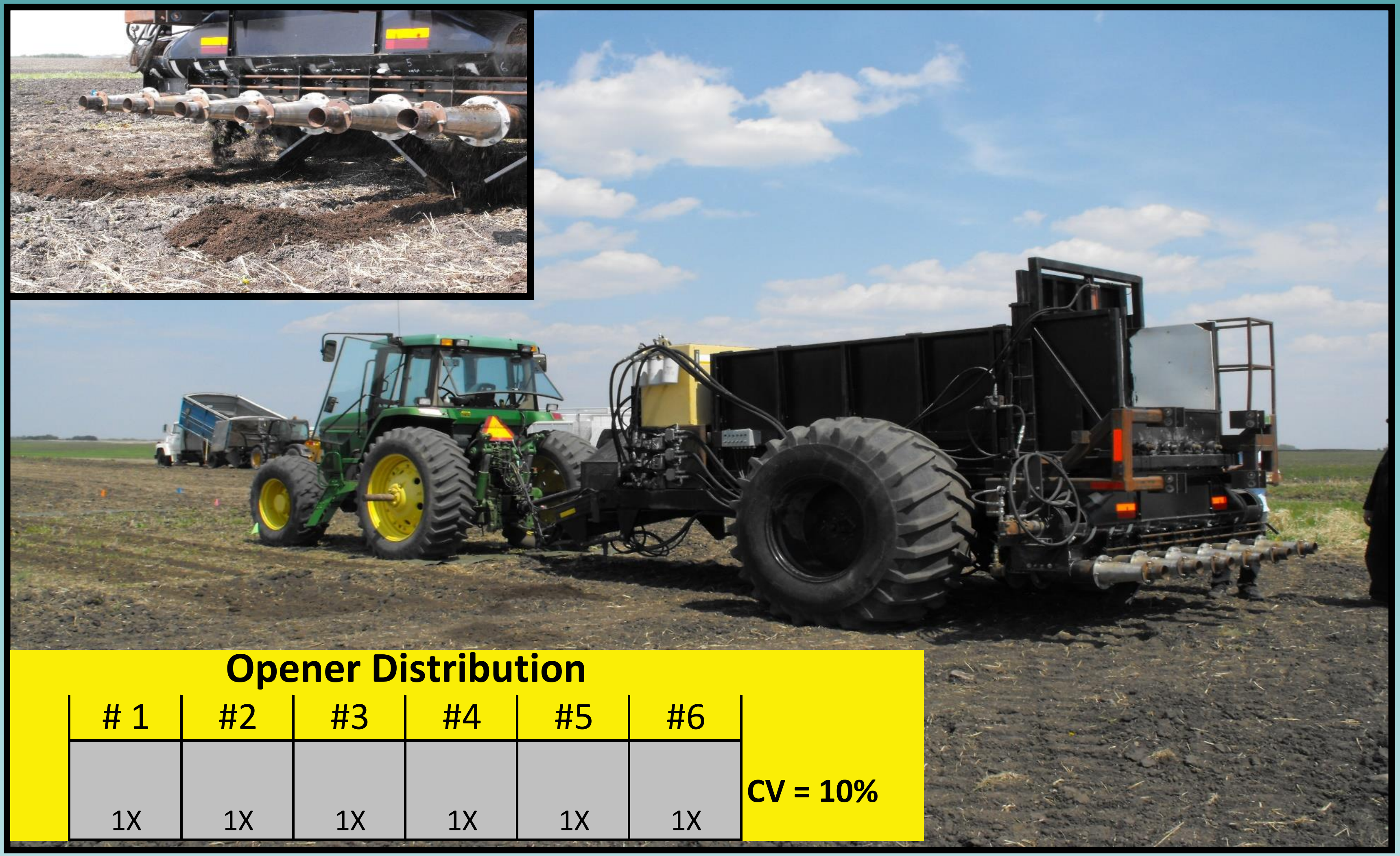
SCM Distribution: 10% C.V.



Opener Distribution

# 1	#2	#3	#4	#5	#6	
1X	1X	1X	1X	1X	1X	**CV = 10%**

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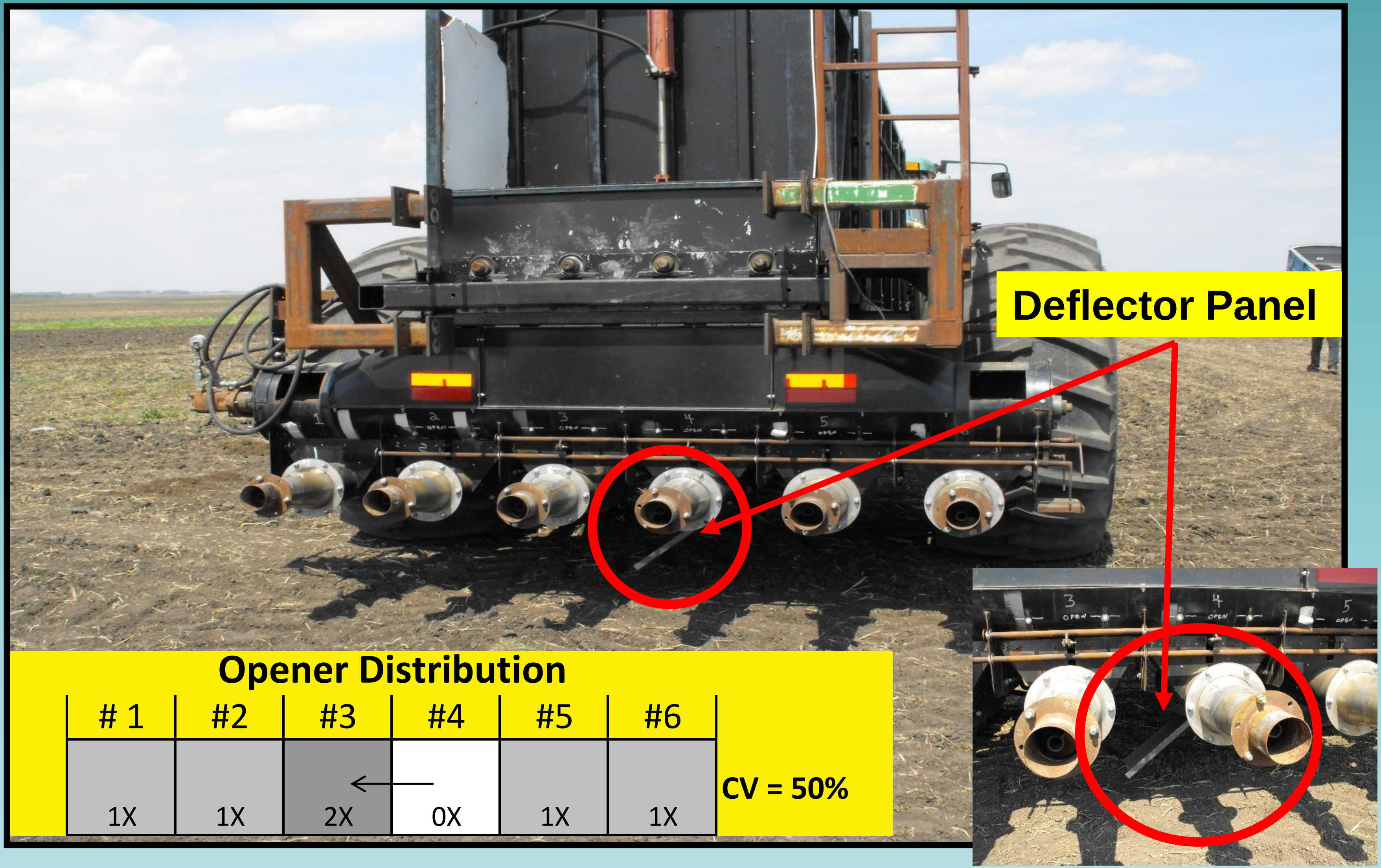
SCM Distribution: 50% C.V.



Opener Distribution

# 1	#2	#3	#4	#5	#6	
1X	1X	2X	0X	1X	1X	**CV = 50%**

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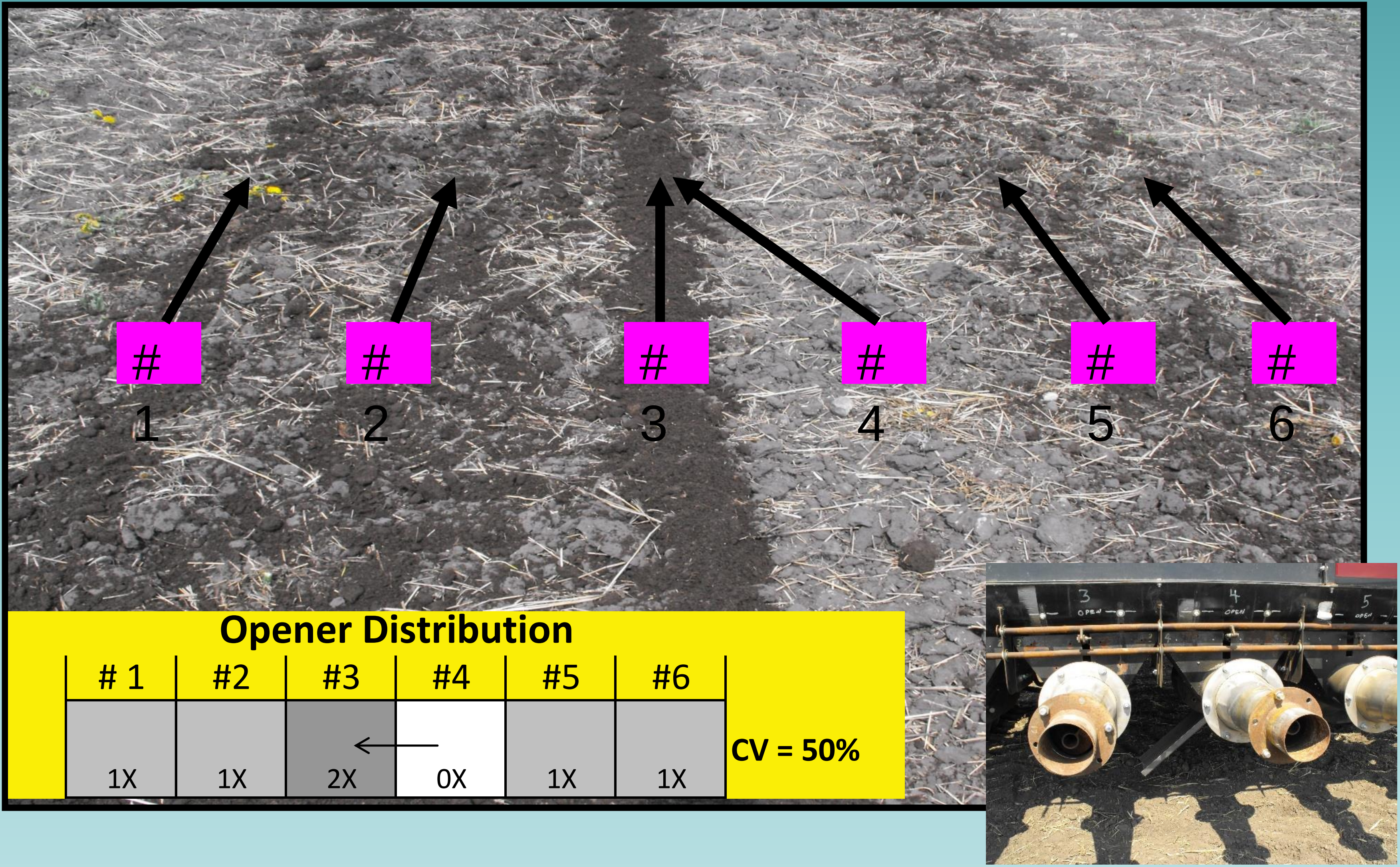
SCM Distribution: 50% C.V.

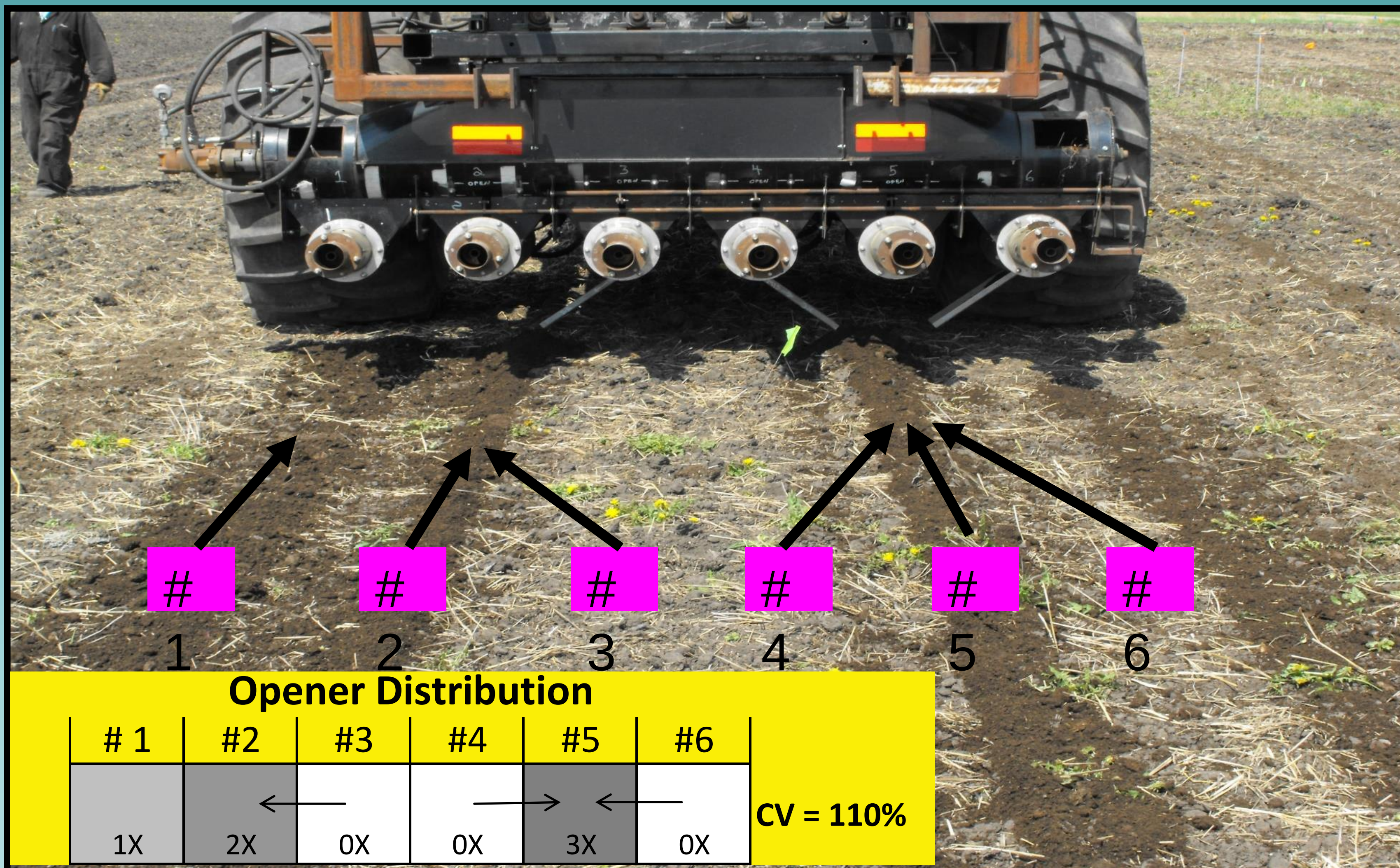


Opener Distribution

# 1	#2	#3	#4	#5	#6	
1X	1X	2X	0X	1X	1X	**CV = 50%**

(Dept. of Soil Science, University of Saskatchewan)

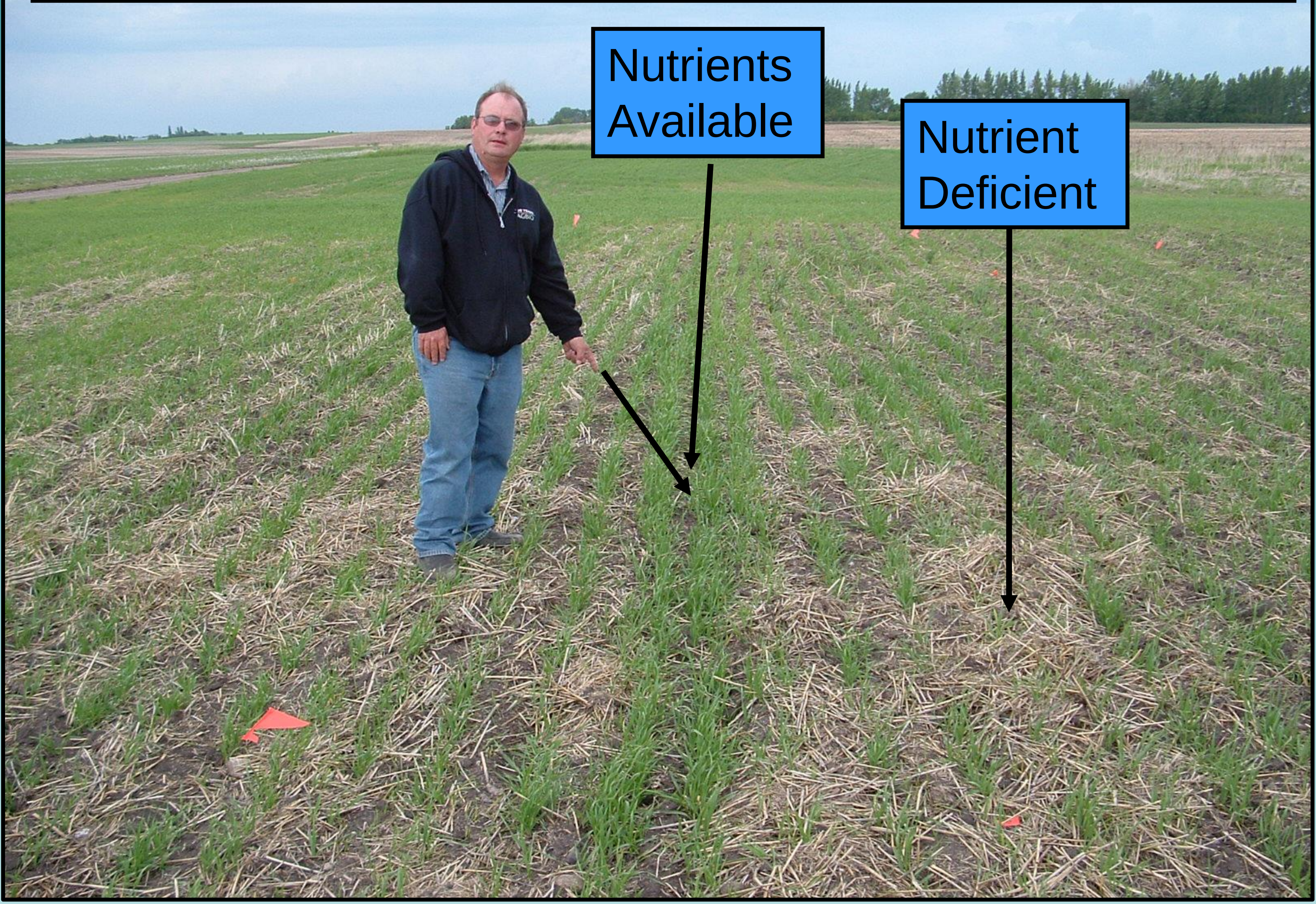
SCM Distribution: 110 % C.V.



# 1	#2	#3	#4	#5	#6
1X	2X	0X	0X	3X	0X

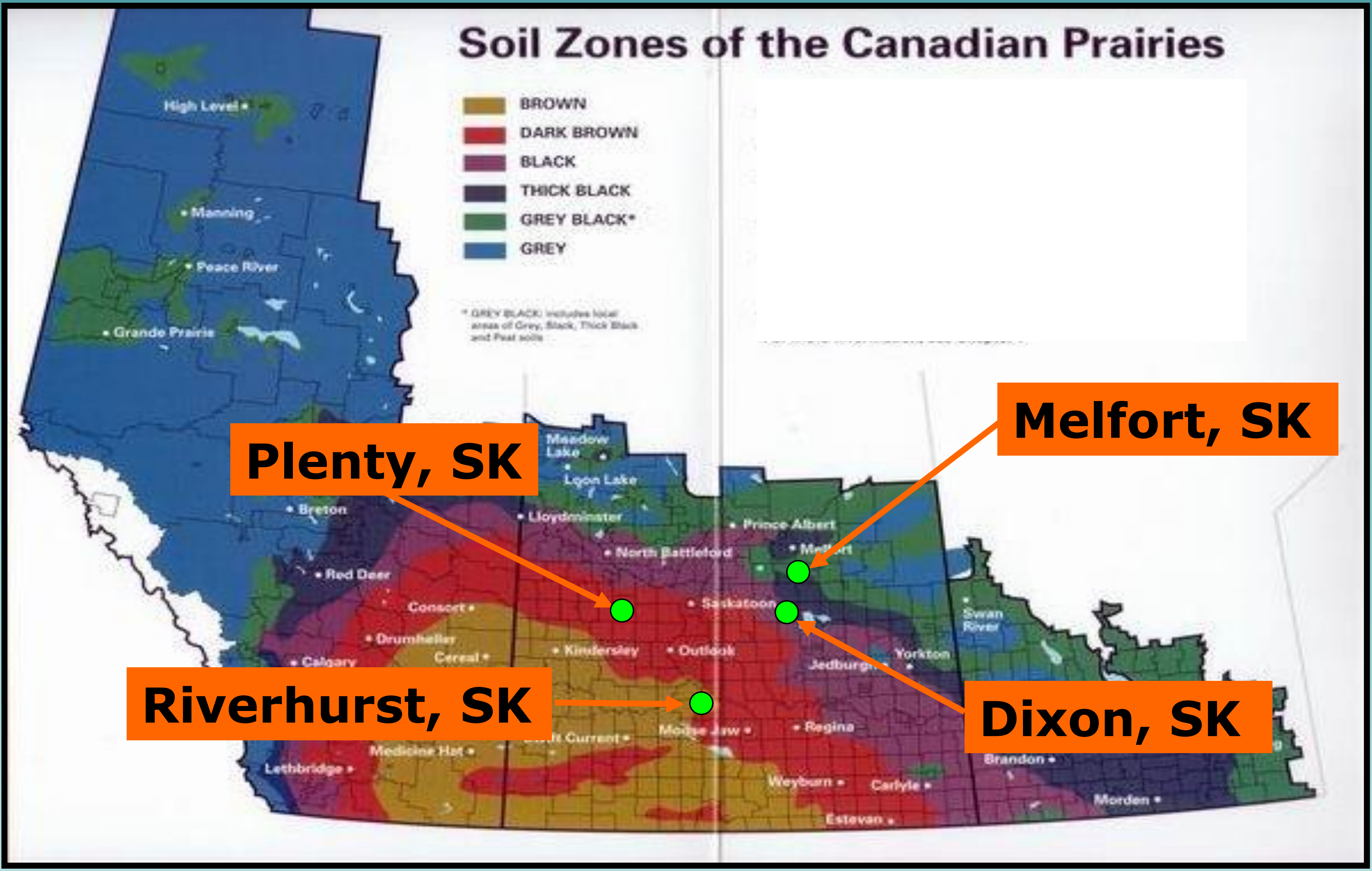
(Dept. of Soil Science, University of Saskatchewan)

High C.V. (110%) 60 t ha^{-1} SCM Rate Application



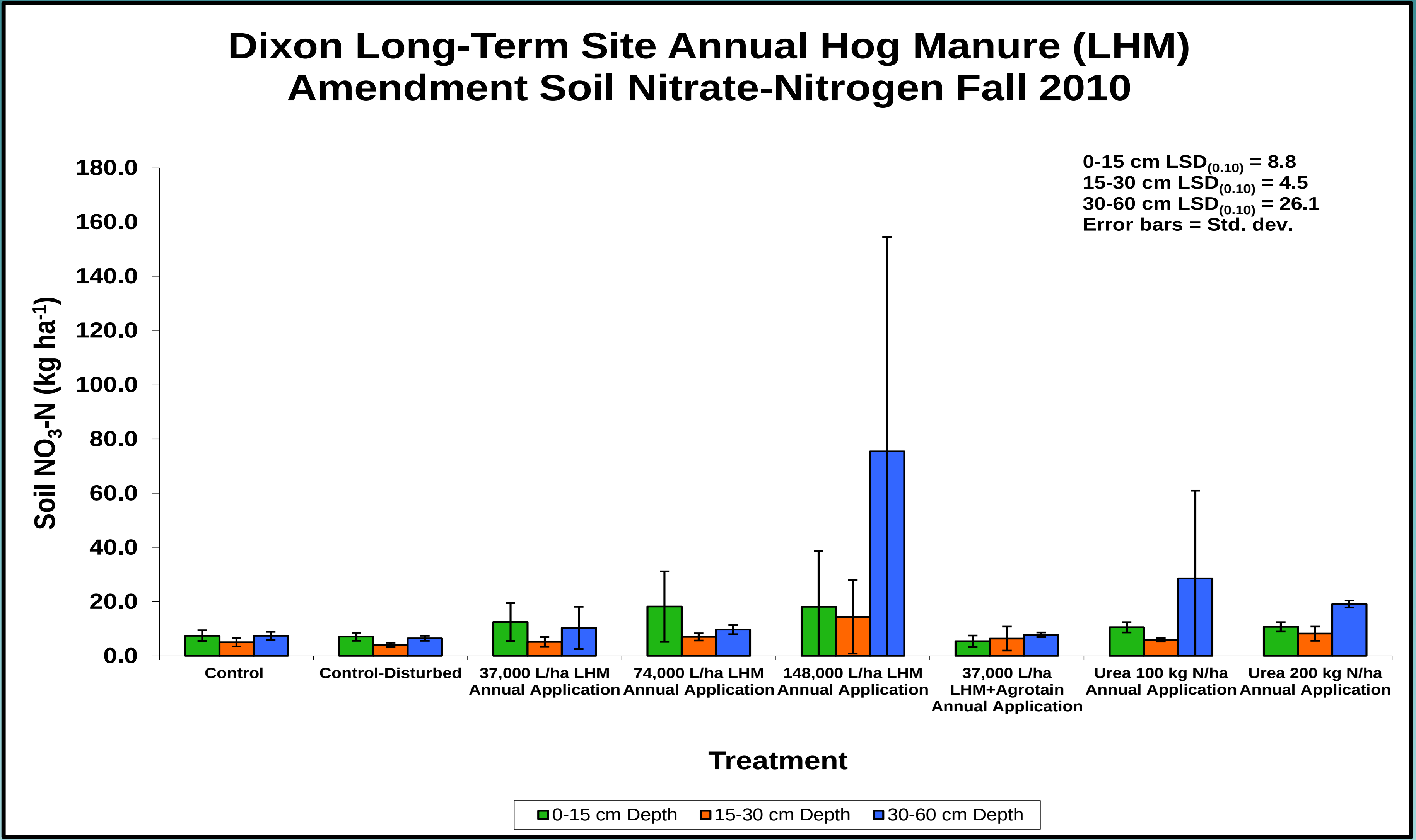
What occurred after cessation of animal manure?

Study Locations (1997–2014)

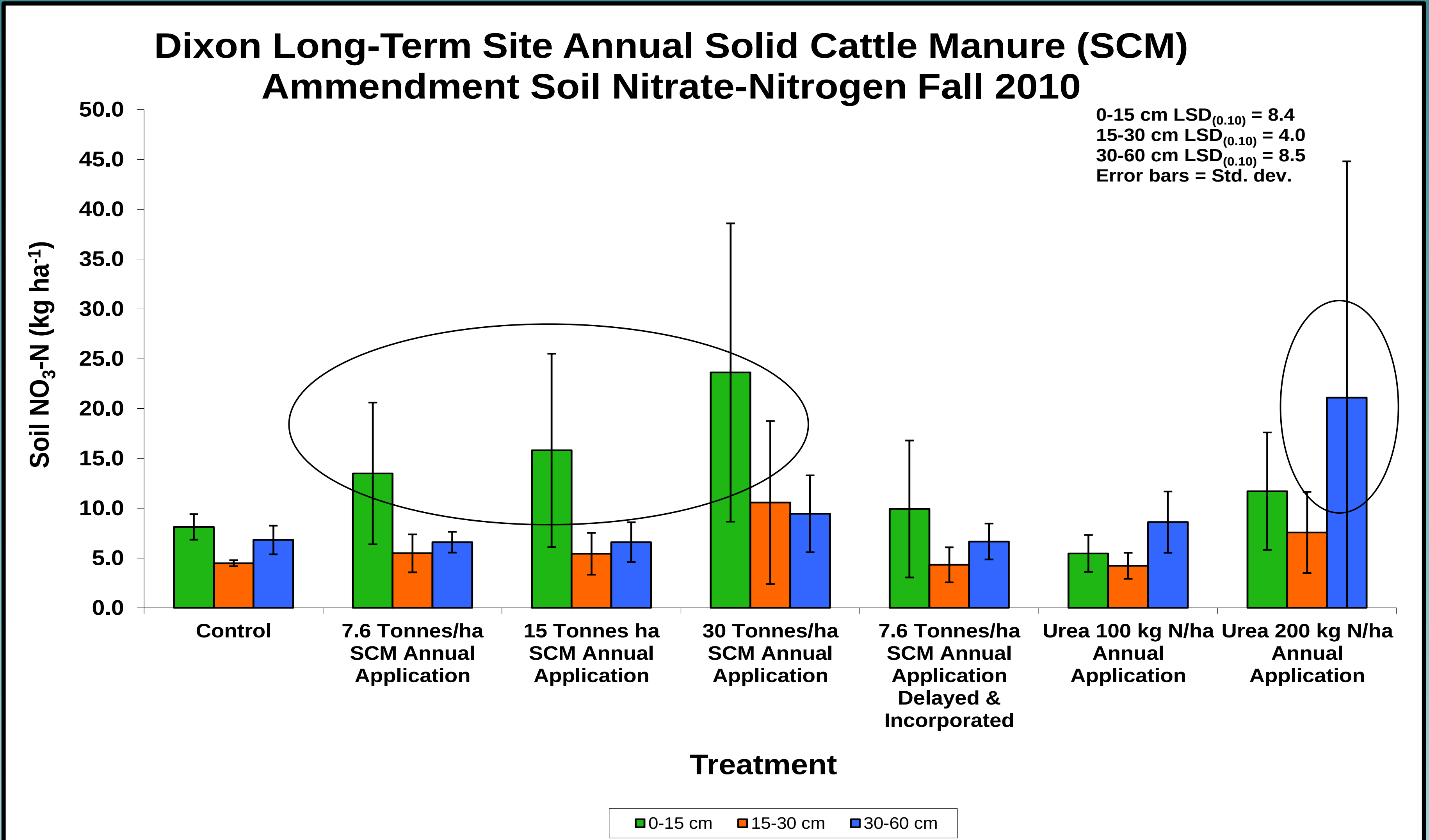


(Henry's Handbook of Soil and Water, 2003)

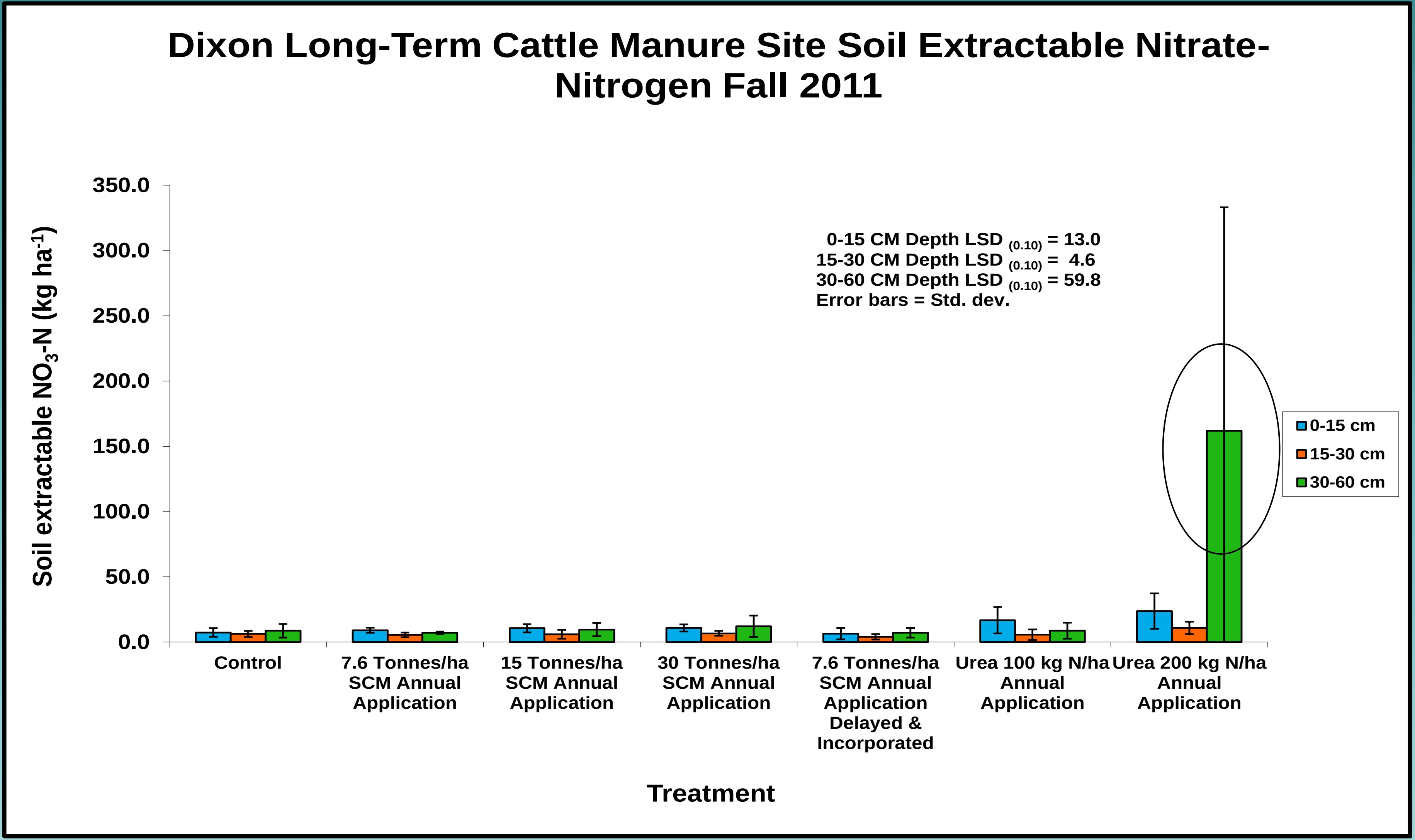
Dixon 1997-2009



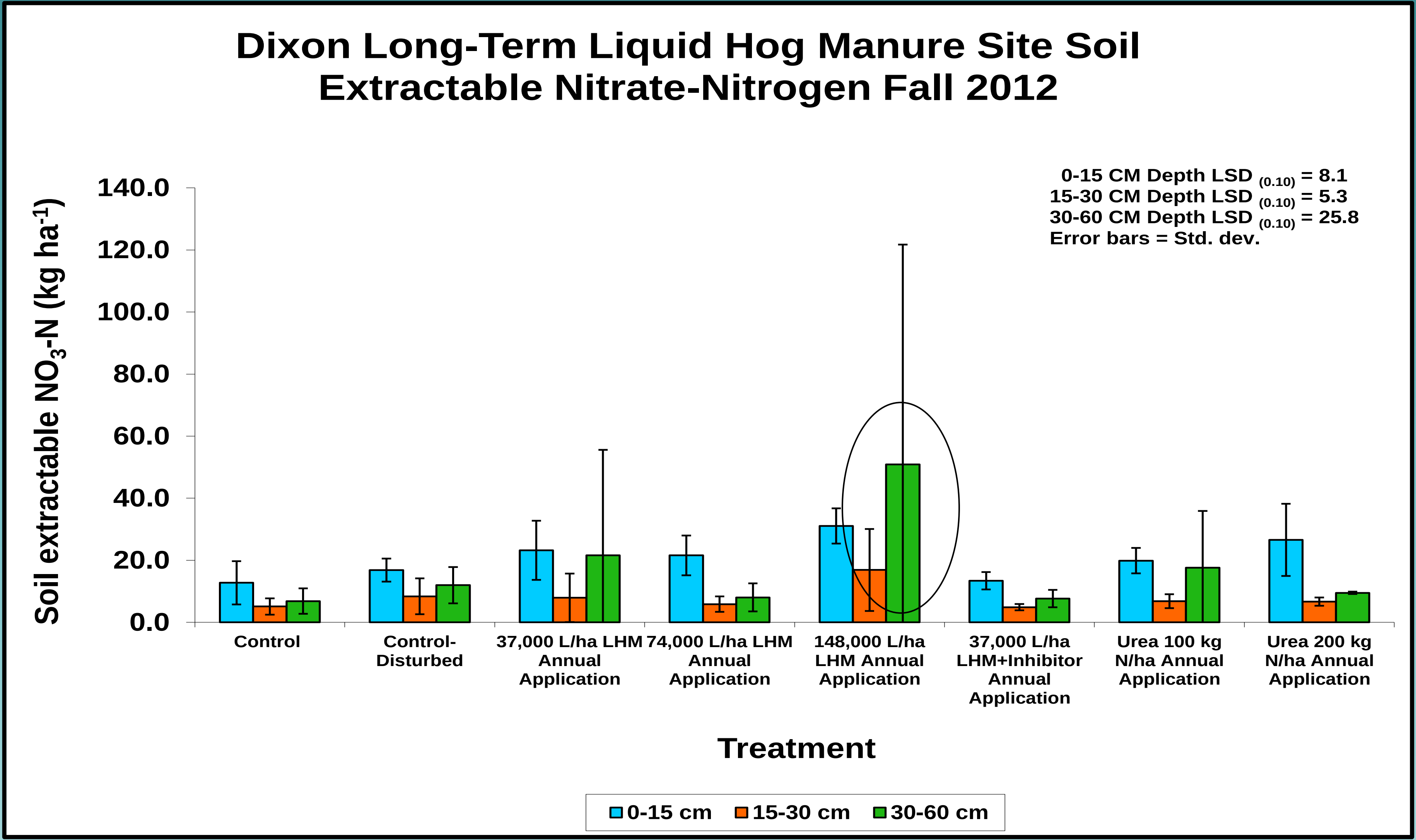
- Significantly elevated levels of soil NO_3-N at 30-60 cm depth in the 148,000 L ha^{-1} rate treatment. Possibly due to very wet 2010 conditions.



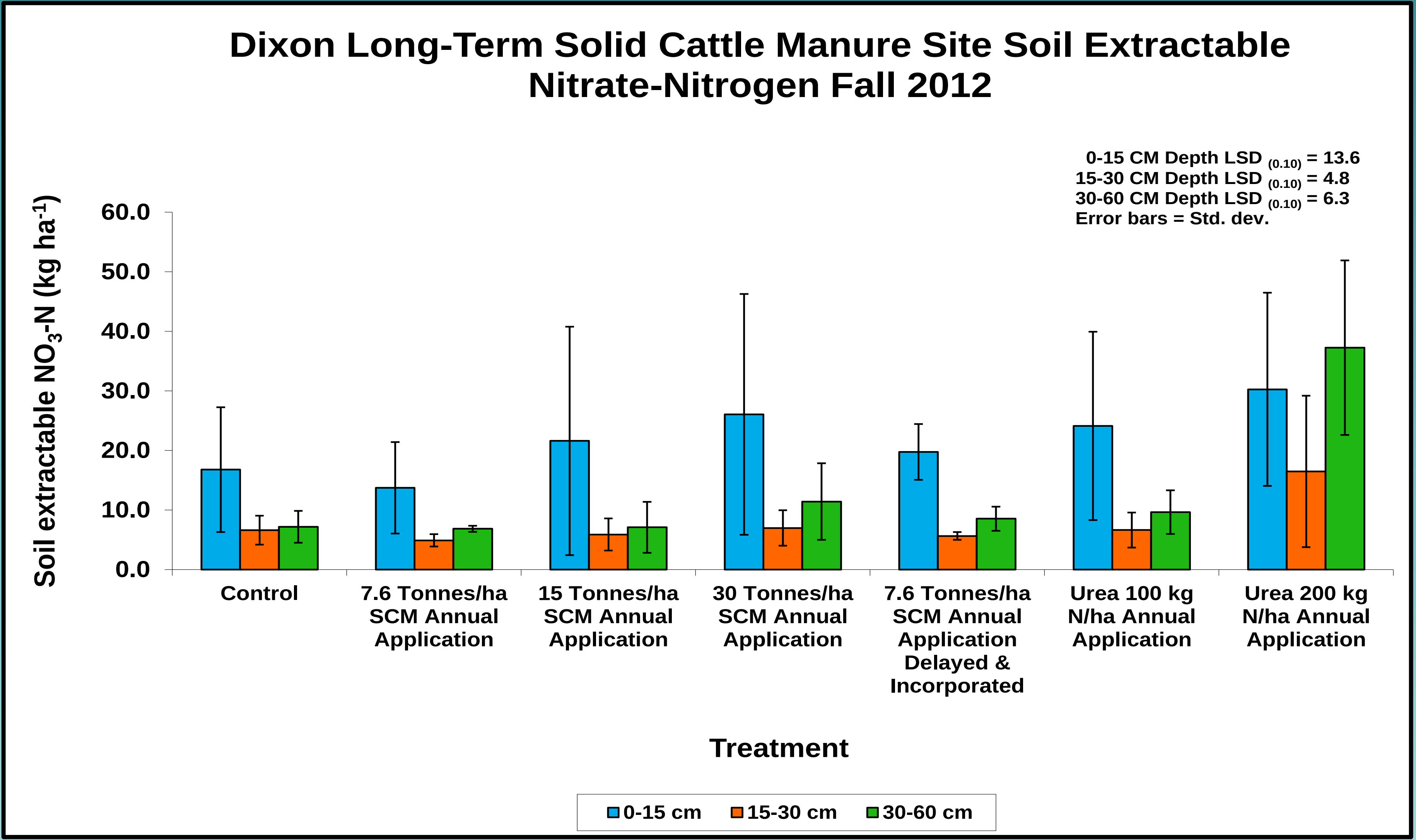
- Significantly elevated levels of soil NO_3-N at 0-15 cm surface depth, increasing as SCM rate increases.



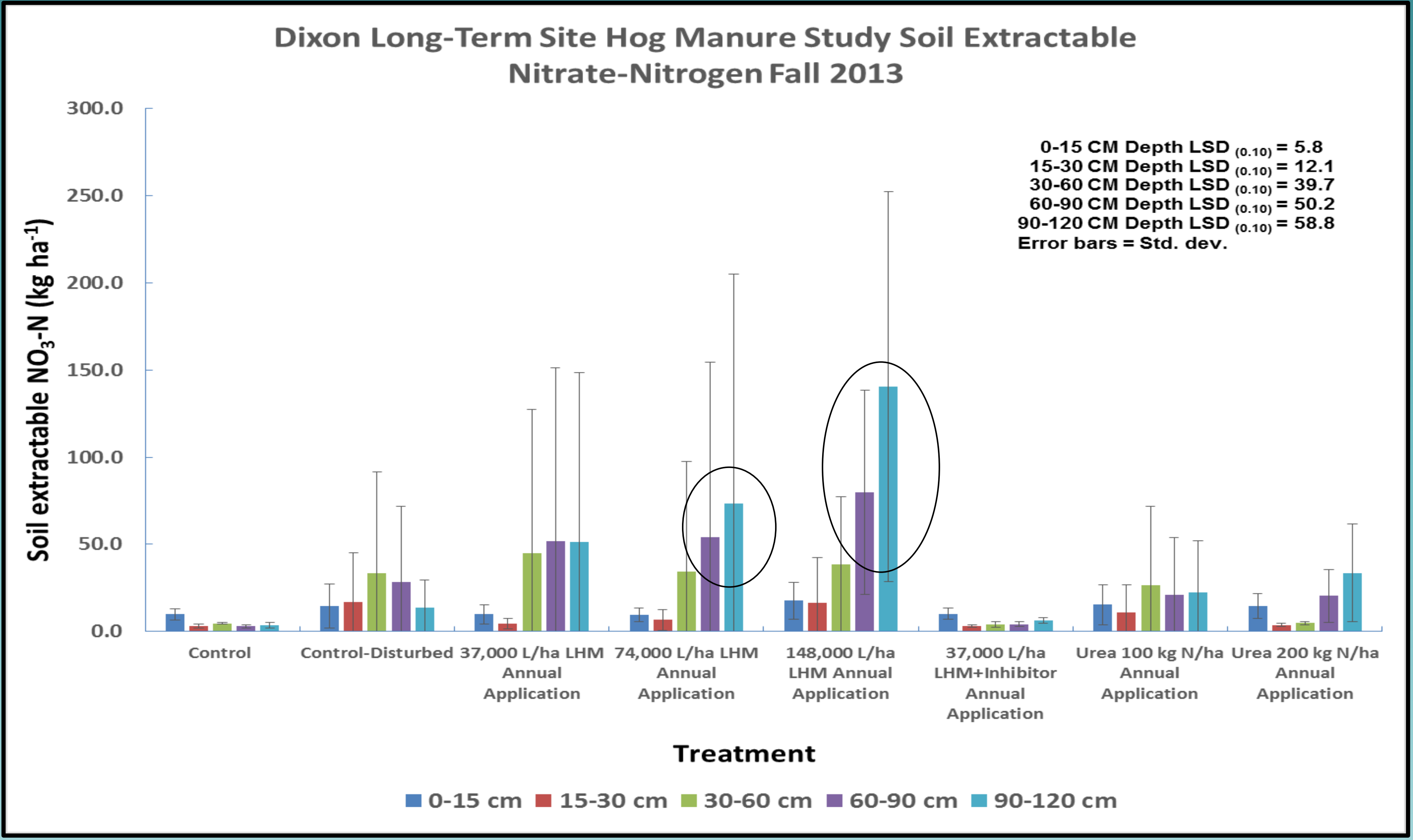
- Lower soil NO_3-N levels, reflecting slower release of available N from SCM, compared to LHM.



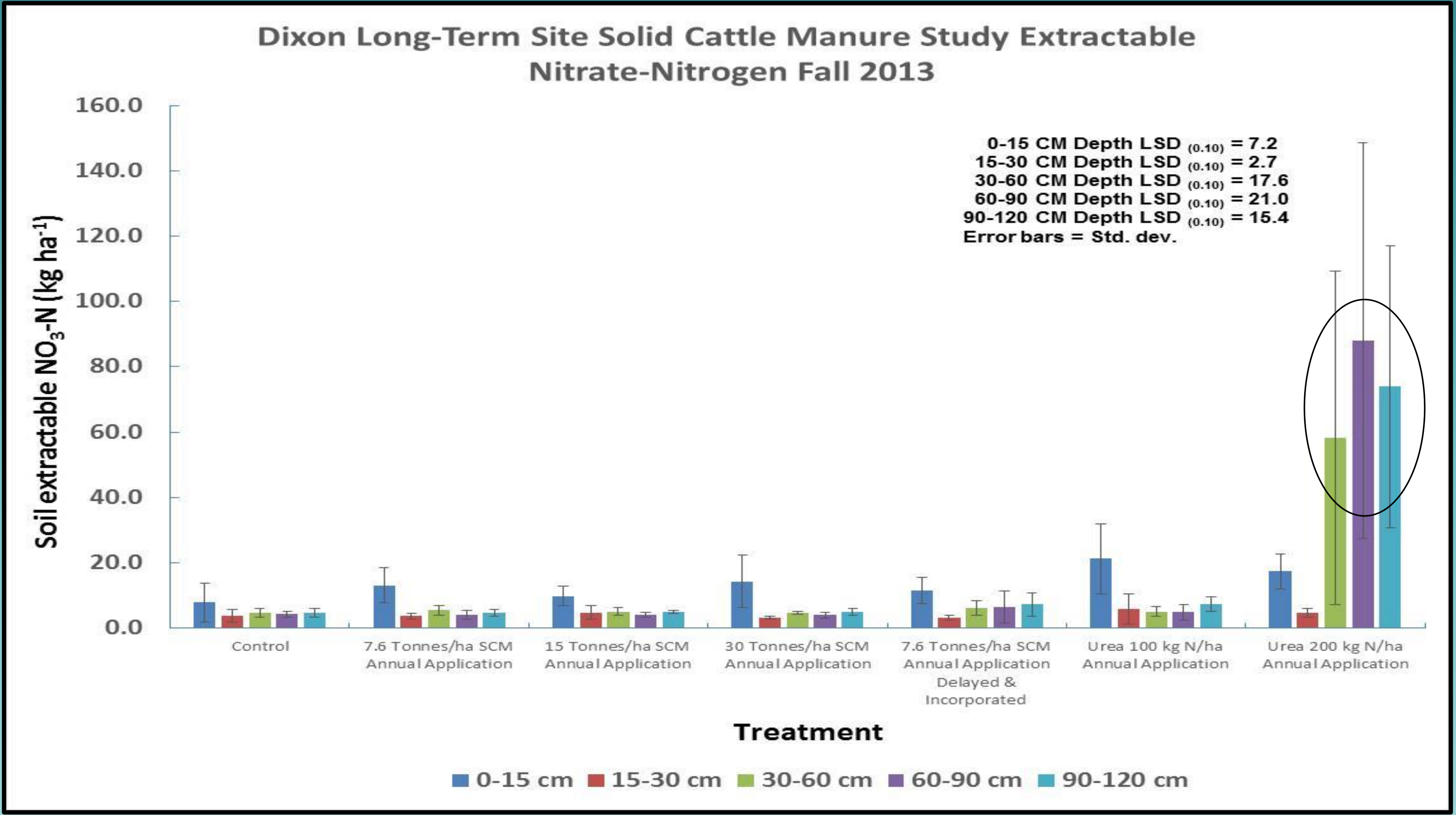
- Excess NO_3-N leached in lower depth due to repeated high application rate from 1997-2010.



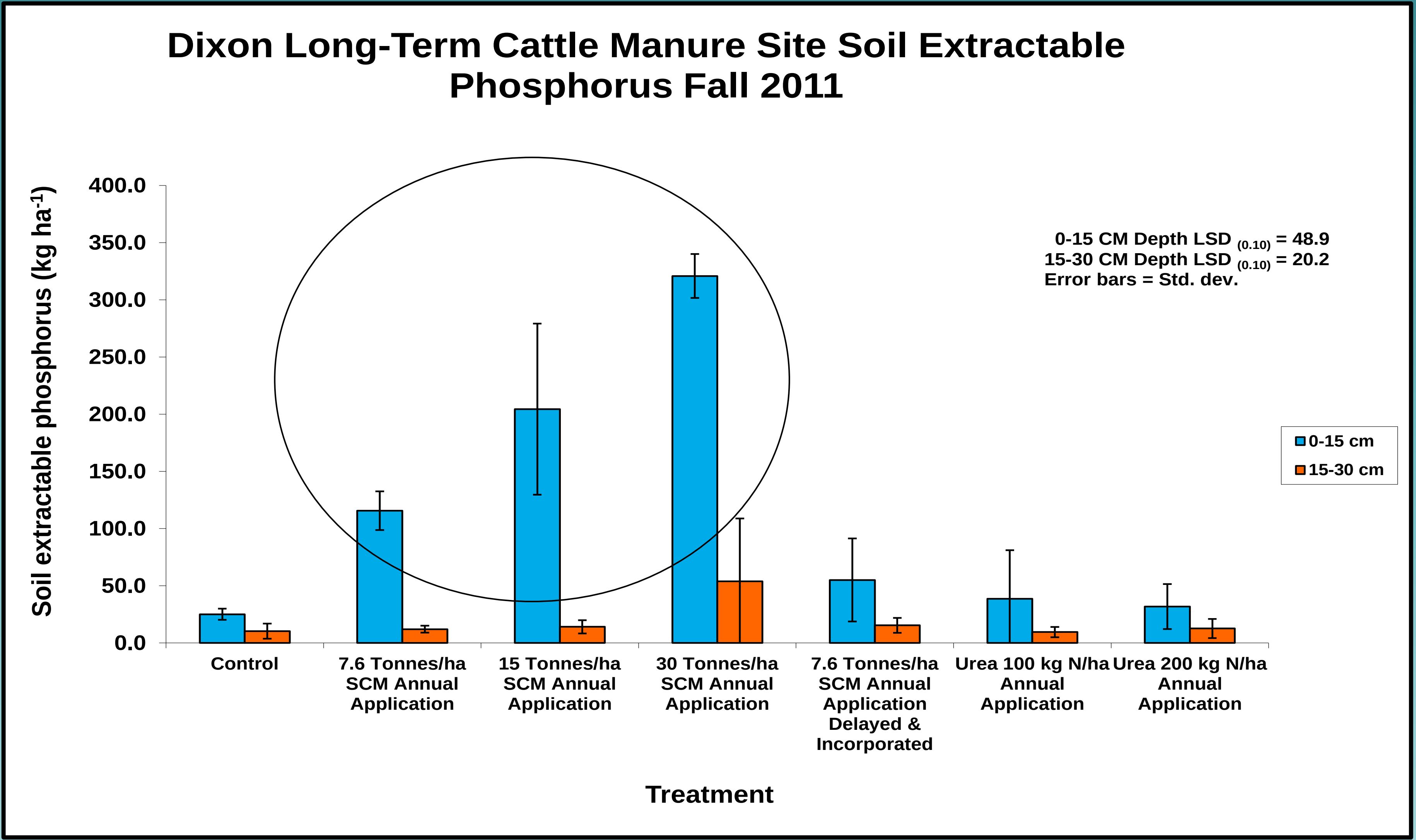
- Slow N availability in SCM reflected in low NO_3-N migration at depth. High urea application over 1997-2009 reflecting leaching of NO_3-N.



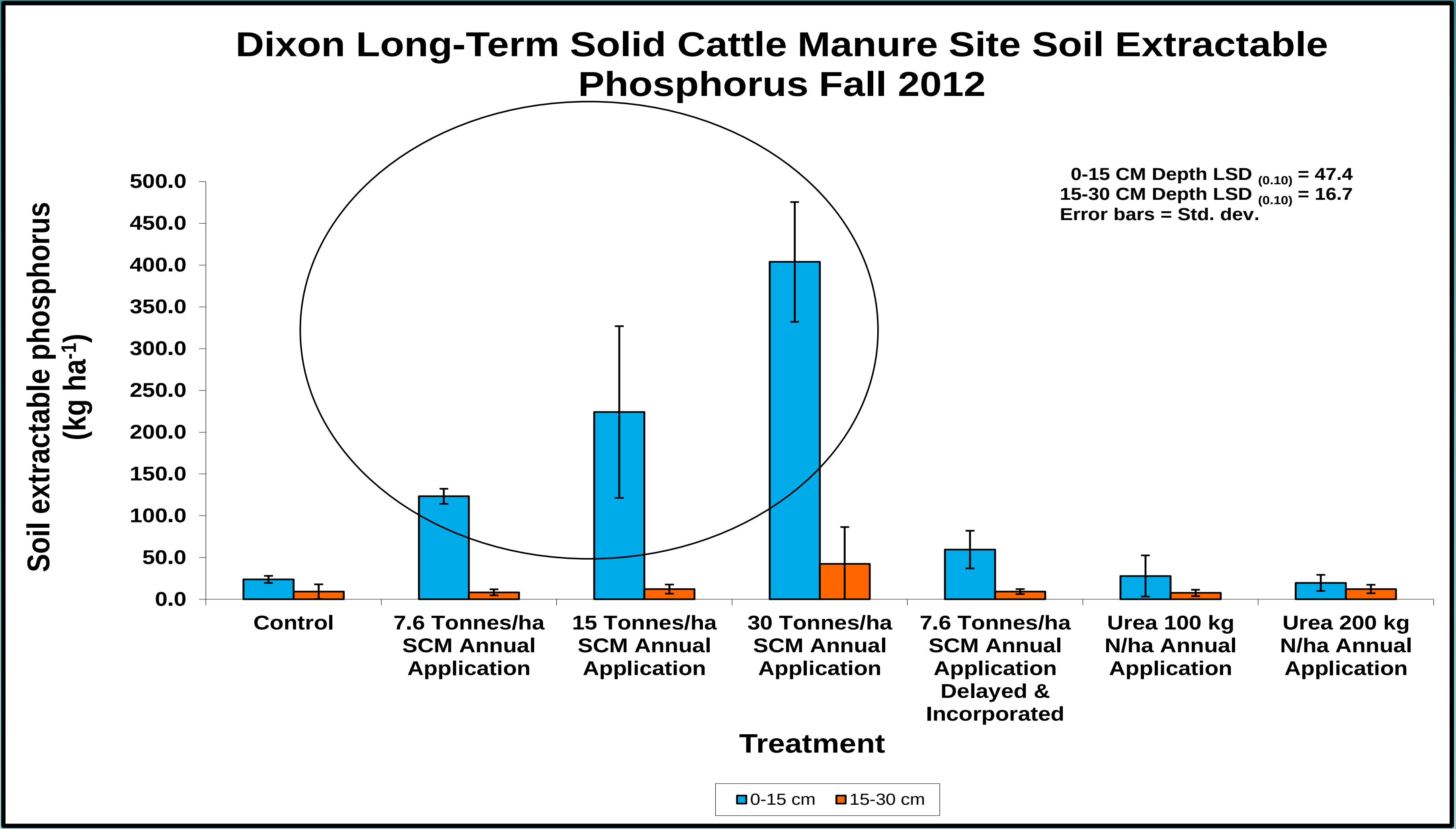
- Movement and accumulation of NO_3-N in LHM at deeper depths from high rate application, 3 years after application ceased.
- Wet conditions contributing to leaching and inability of plant roots to access N at deeper depths.



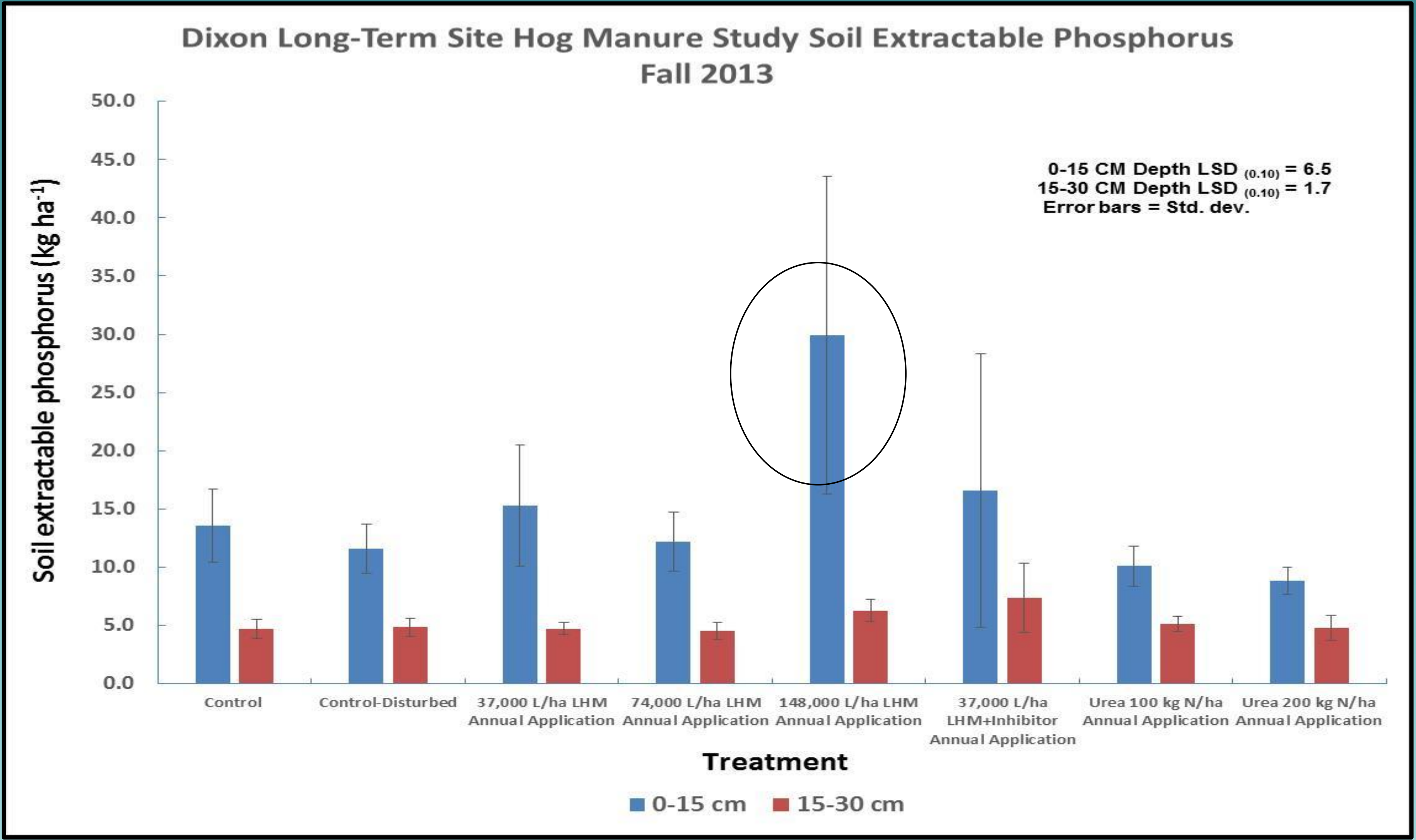
- No accumulation of SCM at depth. Slightly greater NO_3-N at surface, likely a result of post-harvest mineralization of ON due to 14 years of application.
- High rates of urea application over 14 years did lead to NO_3-N accumulation at depth.



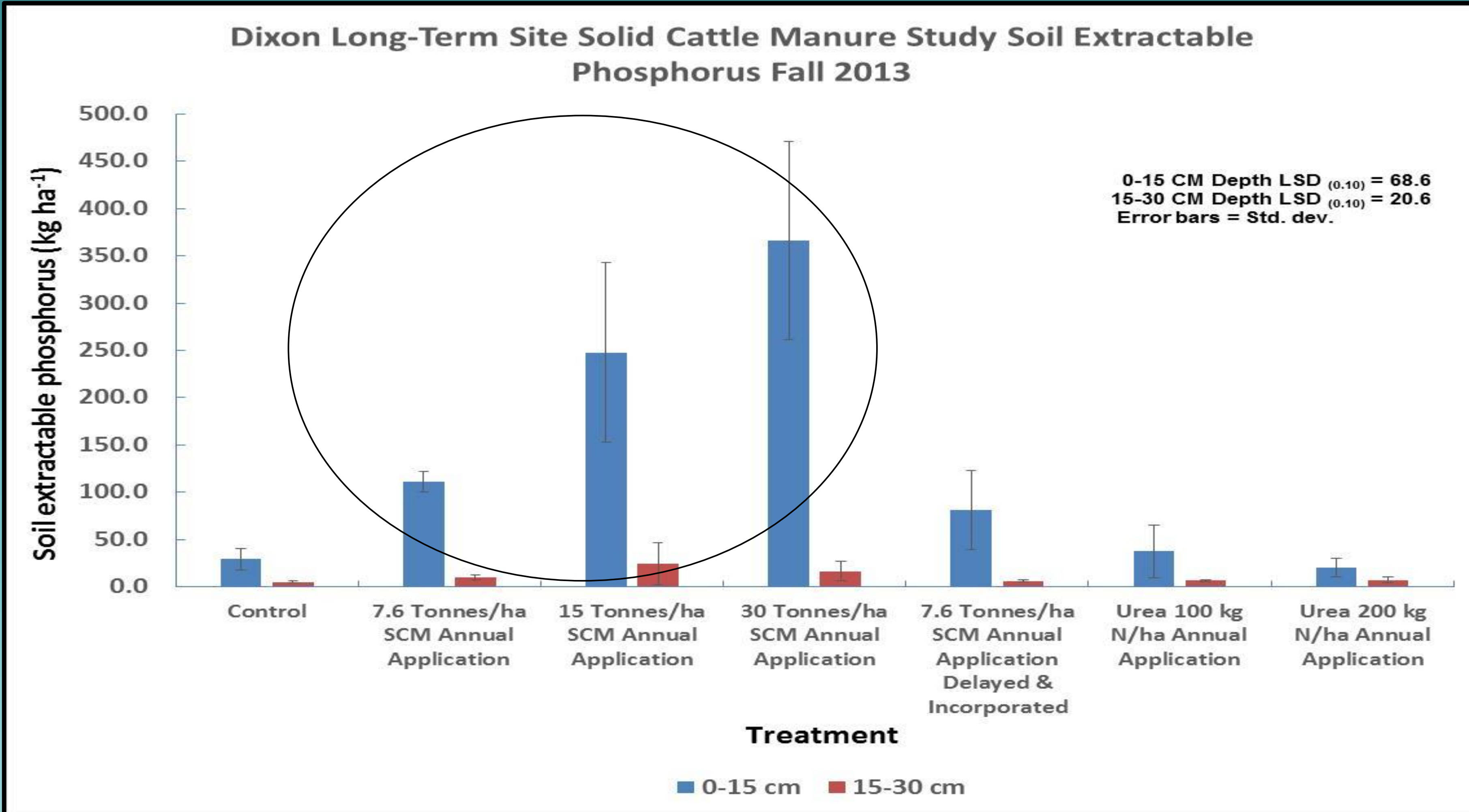
- Significant increase in MK-P as SCM rate increases in 0-15 cm depth, added every year from 1997-2009.



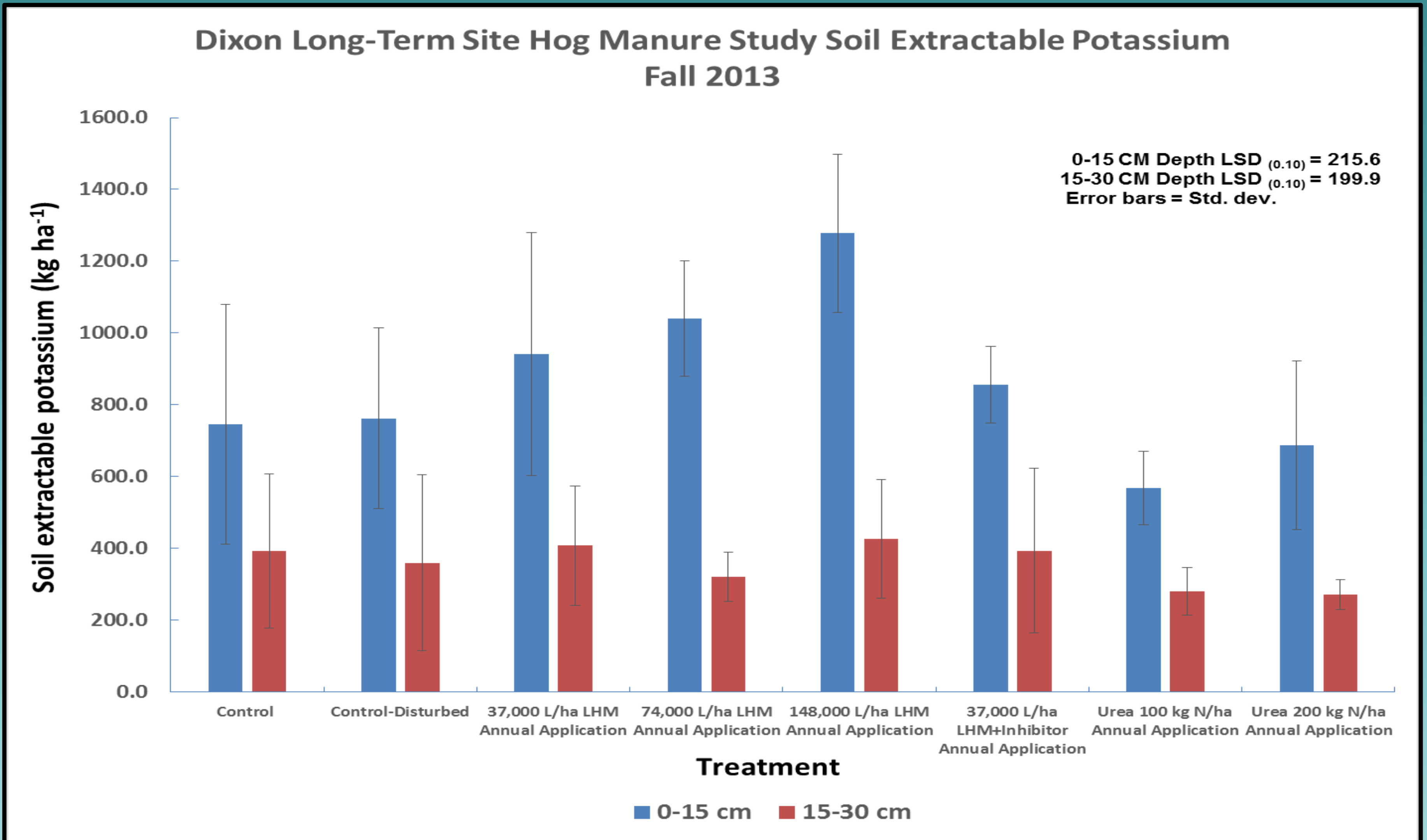
- Soil extractable MK-P levels significantly elevated in 0-15 cm depth, reflecting higher amounts of P in SCM, compared to LHM.
- Also some downward movement (15-30 cm) of P with high rate of SCM application.



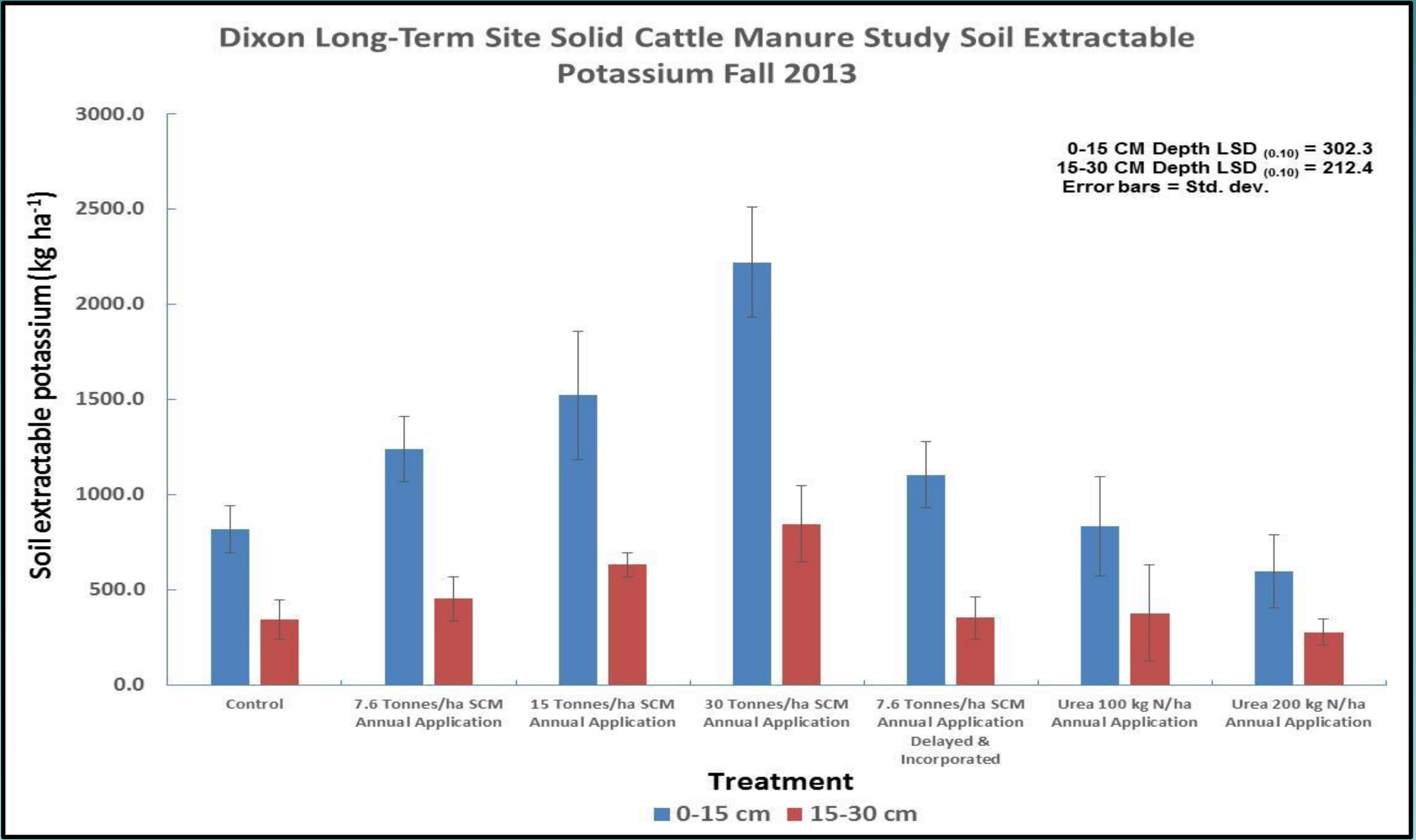
- Only high rate LHM application was observed to elevate soil P to > 30 kg ha^{-1} in surface 0-15 cm.



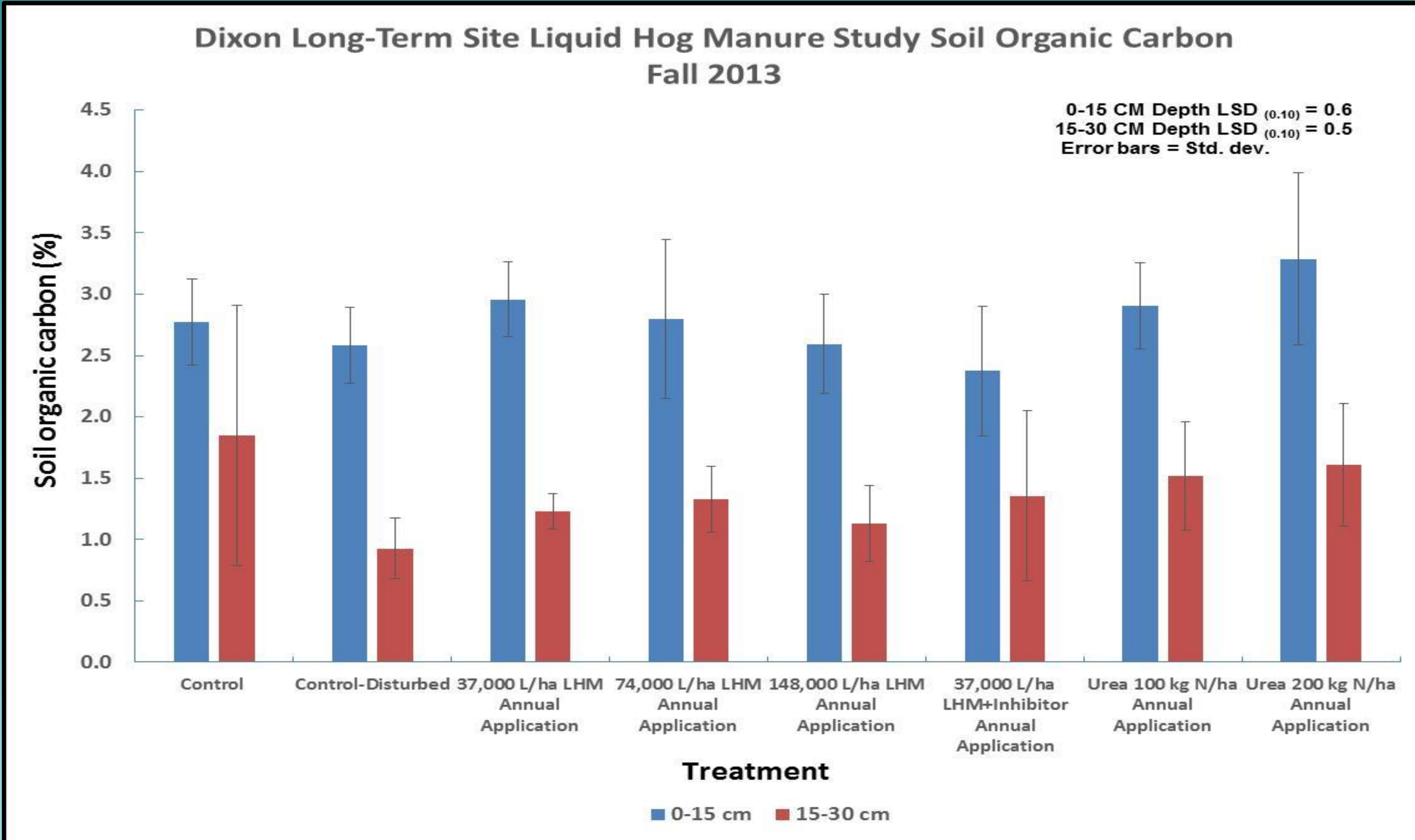
- Compared to LHM (most treatments < 20 kg ha^{-1}), SCM MK-P in 0-15 cm depth increased with increasing application rate - 4 years after application ceased.
- Once P levels elevated, soil P well buffered, thus no additional P need be added.



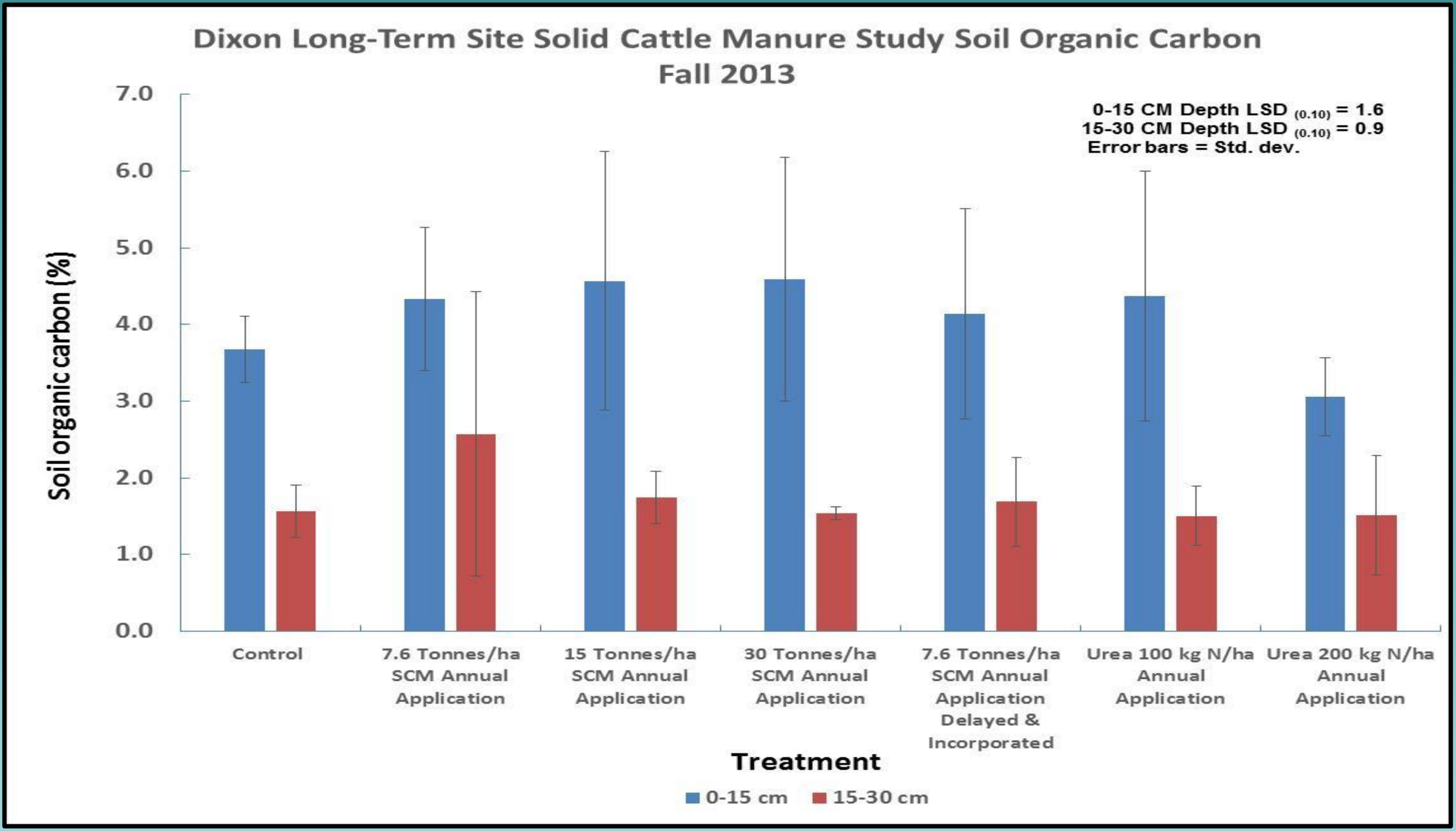
- Elevations in K in 0-15 cm depth as the LHM application rate increased.



- Significant K elevations in SCM as rates increased. Also some migration of K to lower depth, as observed with P in SCM.
- Buffering of K evident - 4 years after application ceased.



- SOC remained relatively unchanged, 4 years after application and similar to measurements made during application years. Little solid material in LHM (> 90% water).

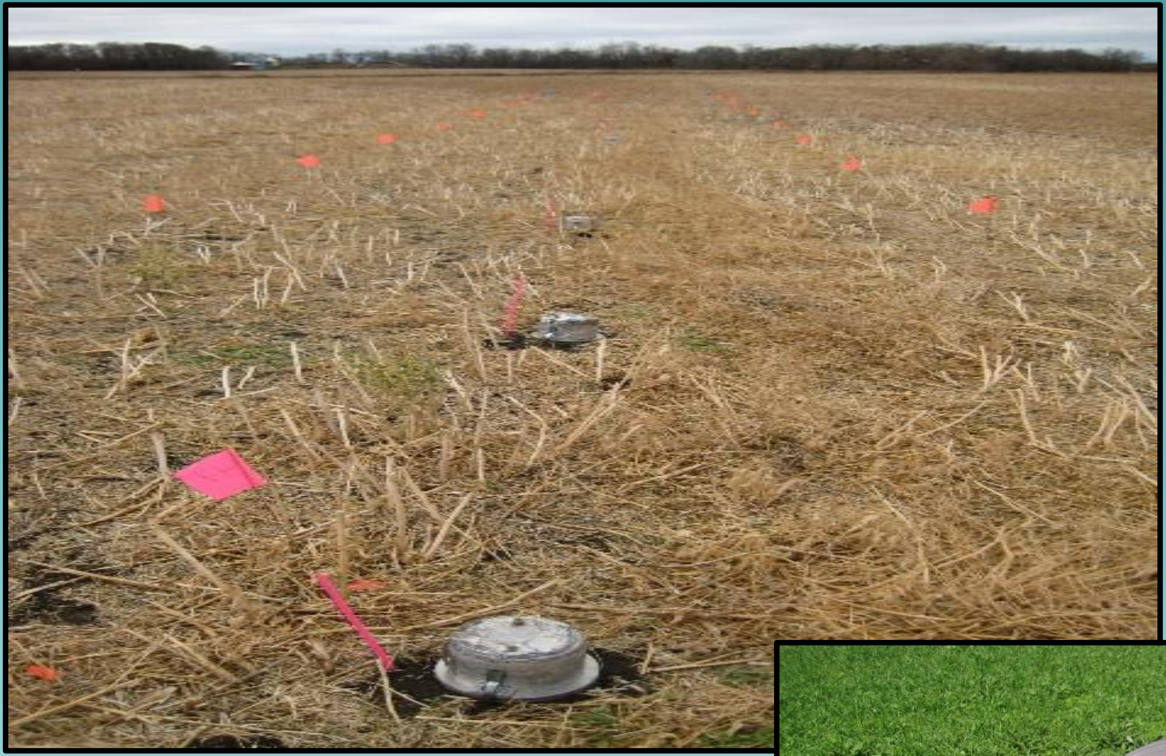


- Compared to LHM (< 3 % SOC), application of SCM over 14 years increased SOC.
- Consequence of large amounts of OM added directly to soil surface and increased plant growth in response to added manure nutrients. SOC persisting over time.

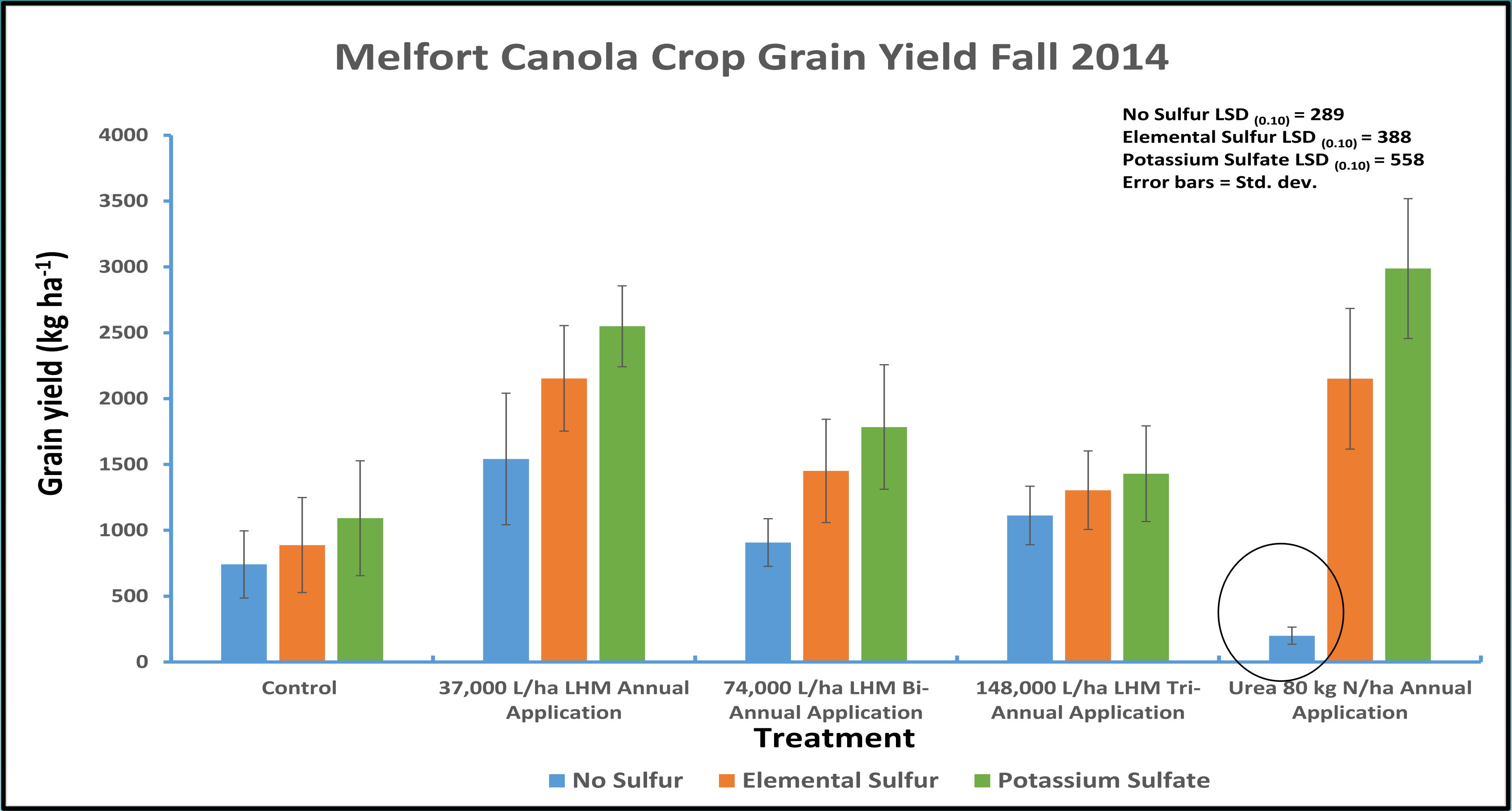
Dixon 1997-2010

- At Dixon site, repeated (14 years) of high rate LHM, resulted in high amounts of NO_3-N leached to lower soil depths: 60-120 cm.
  - Where nitrification inhibitor added, less deep leaching of NO_3-N.
- Recommended that close attention be paid to manure nutrient content (in relation to rates applied) and yearly monitoring of soil NO_3-N, which can be more severe under wet conditions.
- High application rates (60 t ha^{-1}) of SCM led to high soil available P in surface depth and observations of higher P at 15-30 cm depth.
  - Ability of stable fraction to buffer and replenish labile P. Larger increases in SCM OM contributed to mineralization and release of N, years after cessation of application.
- No detectable increase in salinity, although manure adds salts to soil.
- Soil pH relatively unaffected by manure application over 14 years.
- SCM increased SOC, compared to LHM, owing to fact that SCM contains greater amounts of OM and possibly recalcitrant nature of OM formed in soil.

Dixon Greenhouse Gas Sampling



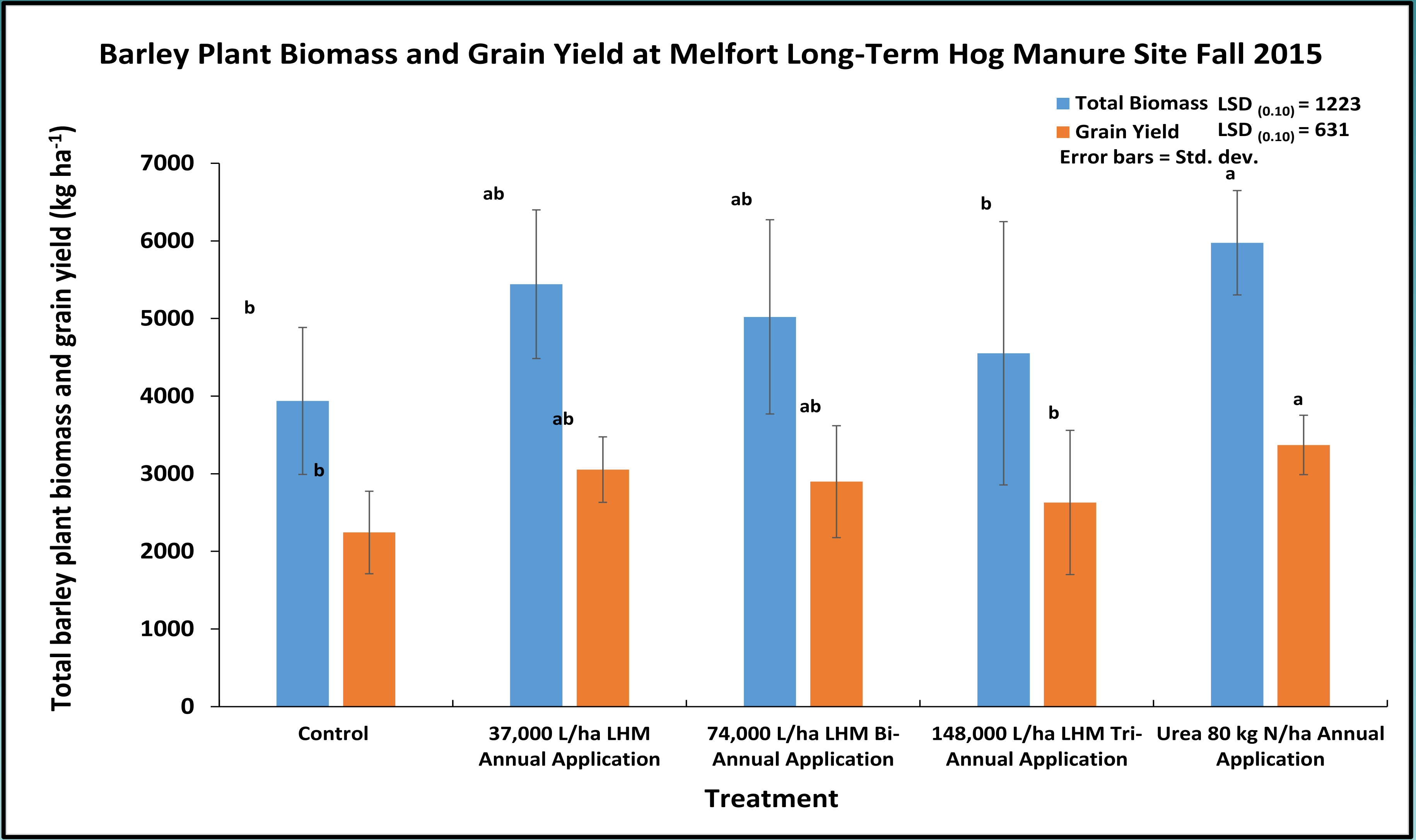
Melfort 1999-2014



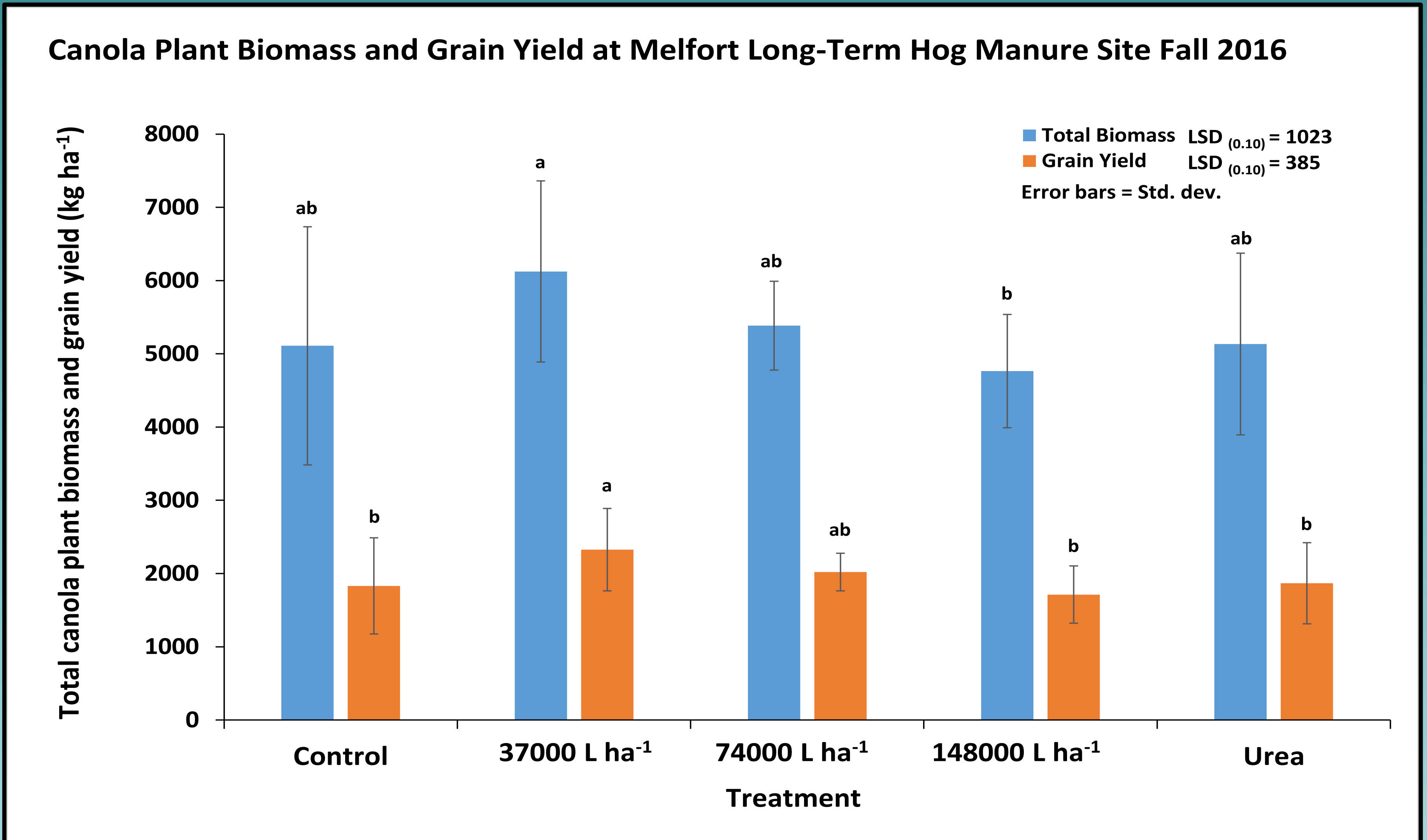
- Final year of application of LHM, significant yield effect in annual 37,000 L ha^{-1} application. LHM + S also producing significant grain yields.
- Site is low in S and canola continued to produce more grain when added with LHM, compared to no LHM and S. Combination of urea + S produced very good canola yields.


Urea (N only) applied at 80 kg N ha-1

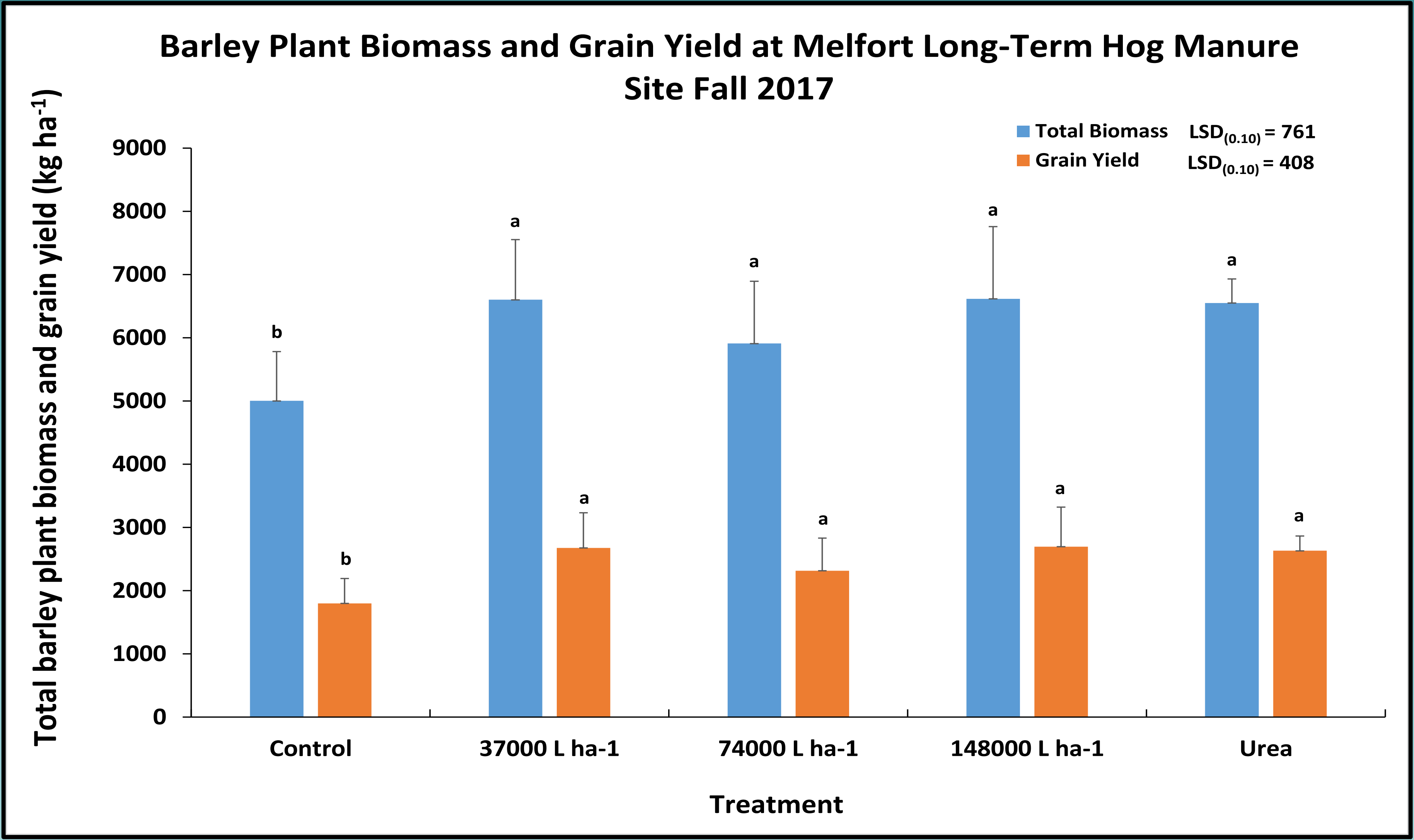

Urea + K2SO4



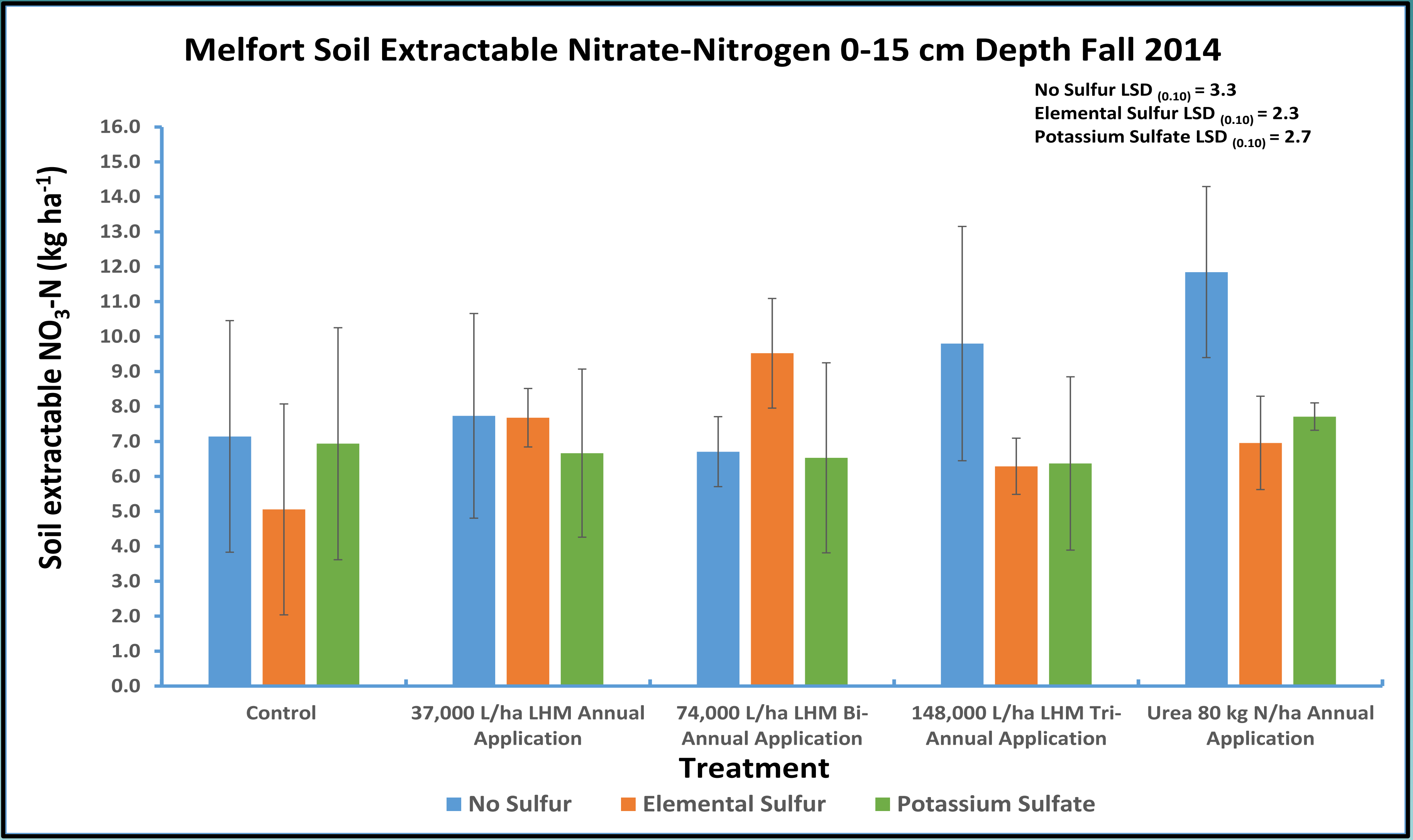
- 1 year after cessation of LHM, annual 37,000 L ha^{-1} and bi-annual 74,000 L ha^{-1} LHM treatments producing higher amounts of grain yield.



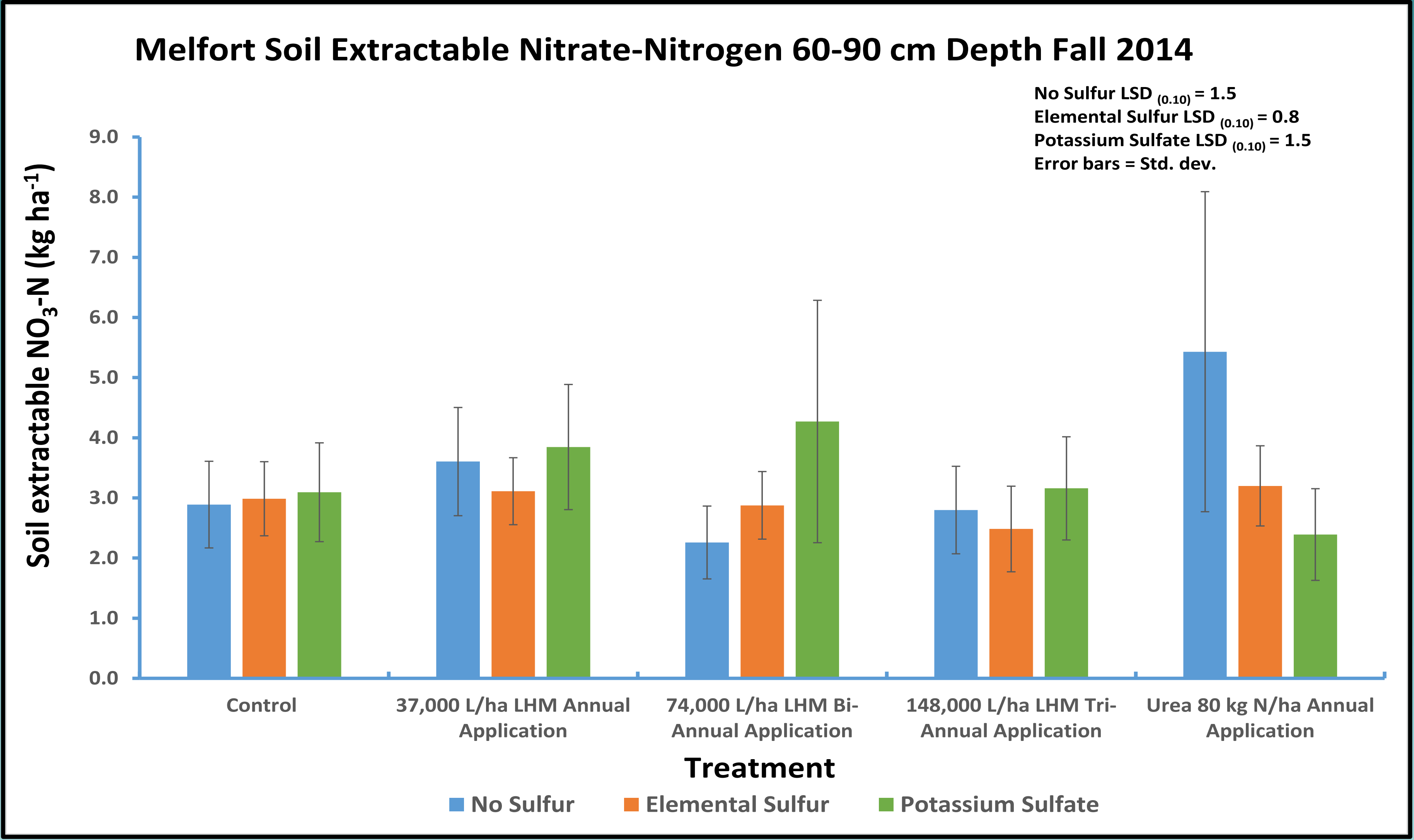
- 2 years after cessation of LHM, effect of annual 37,000 L ha^{-1} rate on canola grain yield.



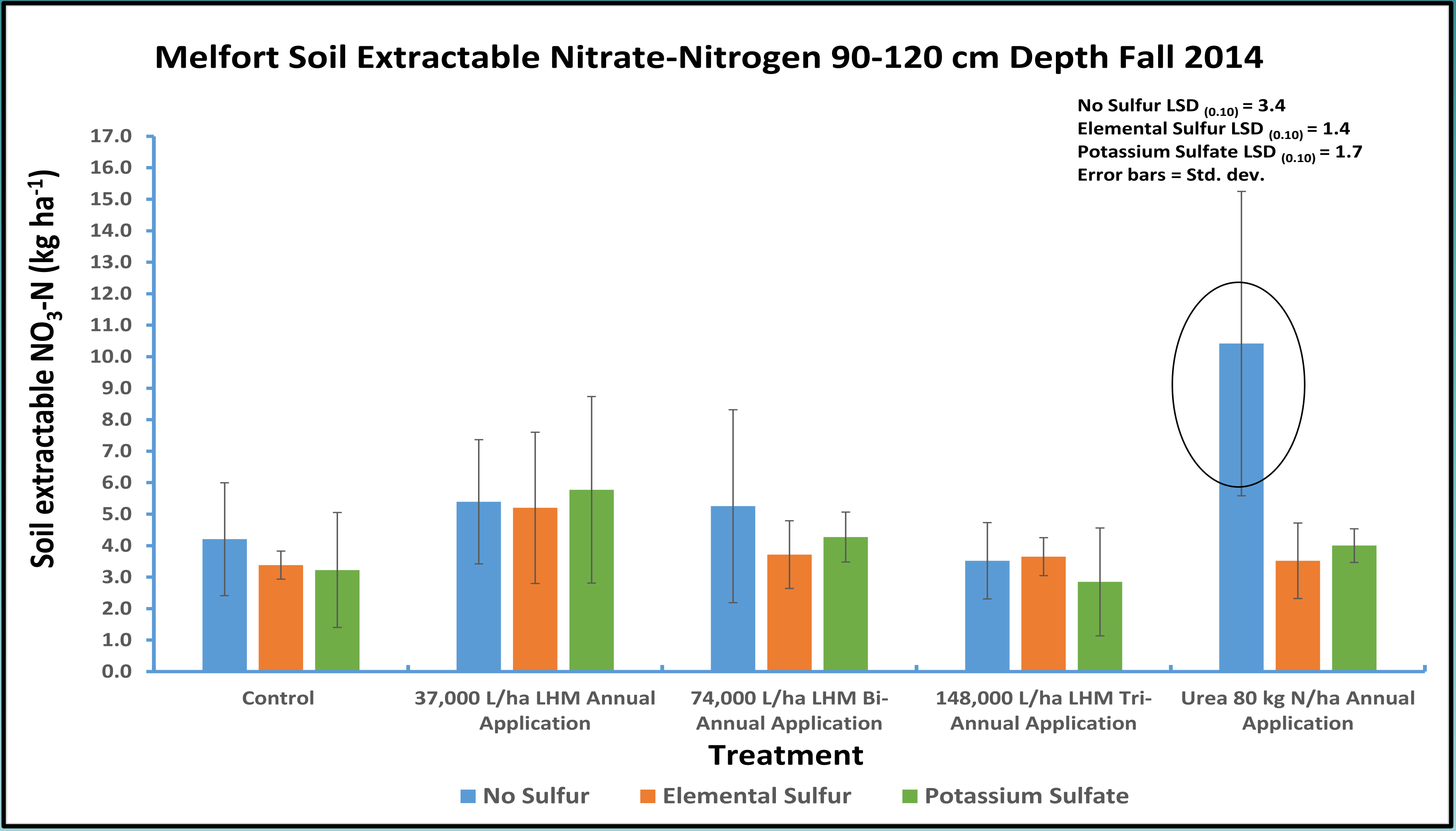
- 3 years after cessation of LHM, still seeing significant effect on grain yields, compared to unfertilized control treatment.



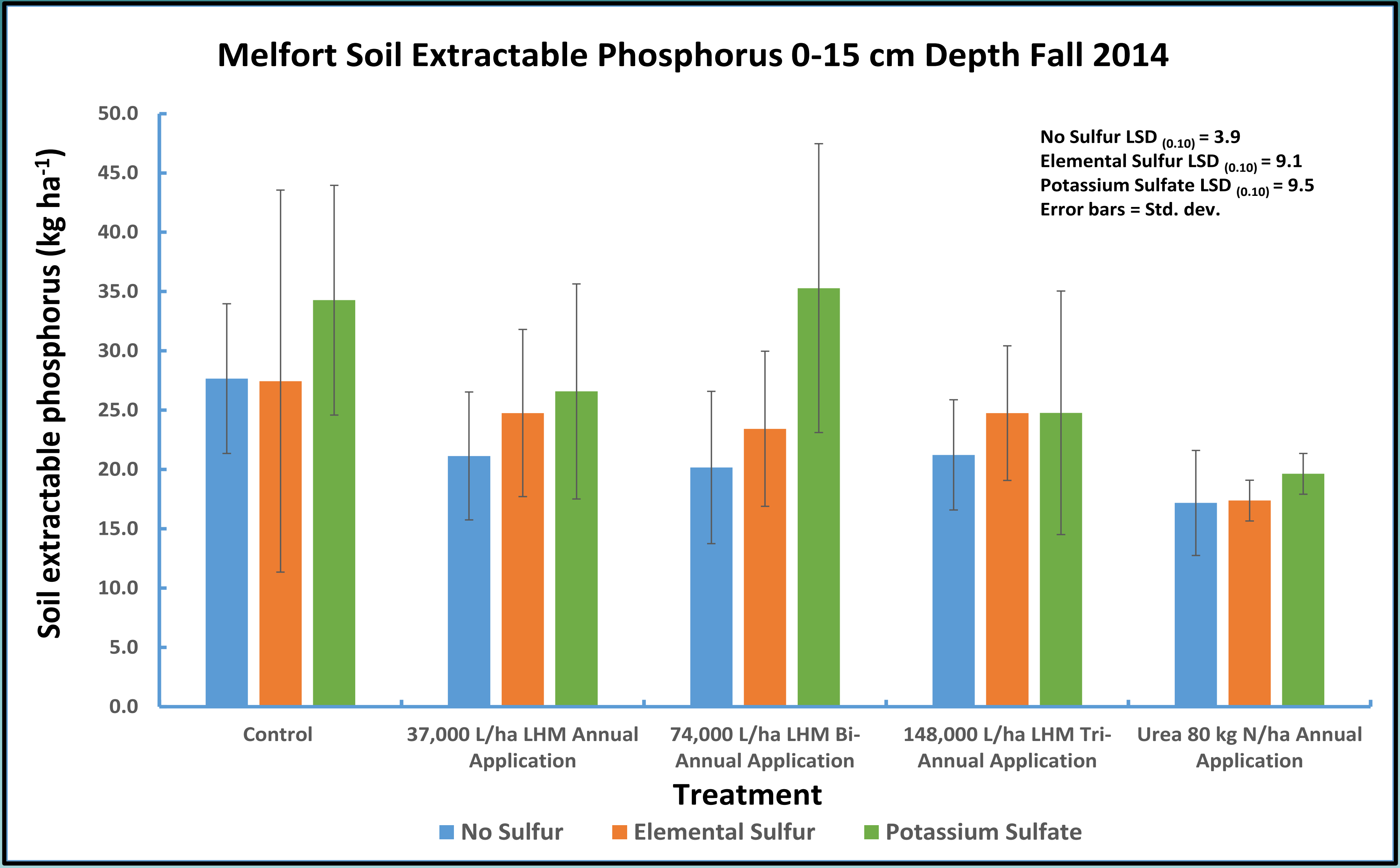
- Some buildup in soil NO_3-N in 0-15 cm depth in the 148,000 L ha^{-1} and urea fertilized treatment plots.



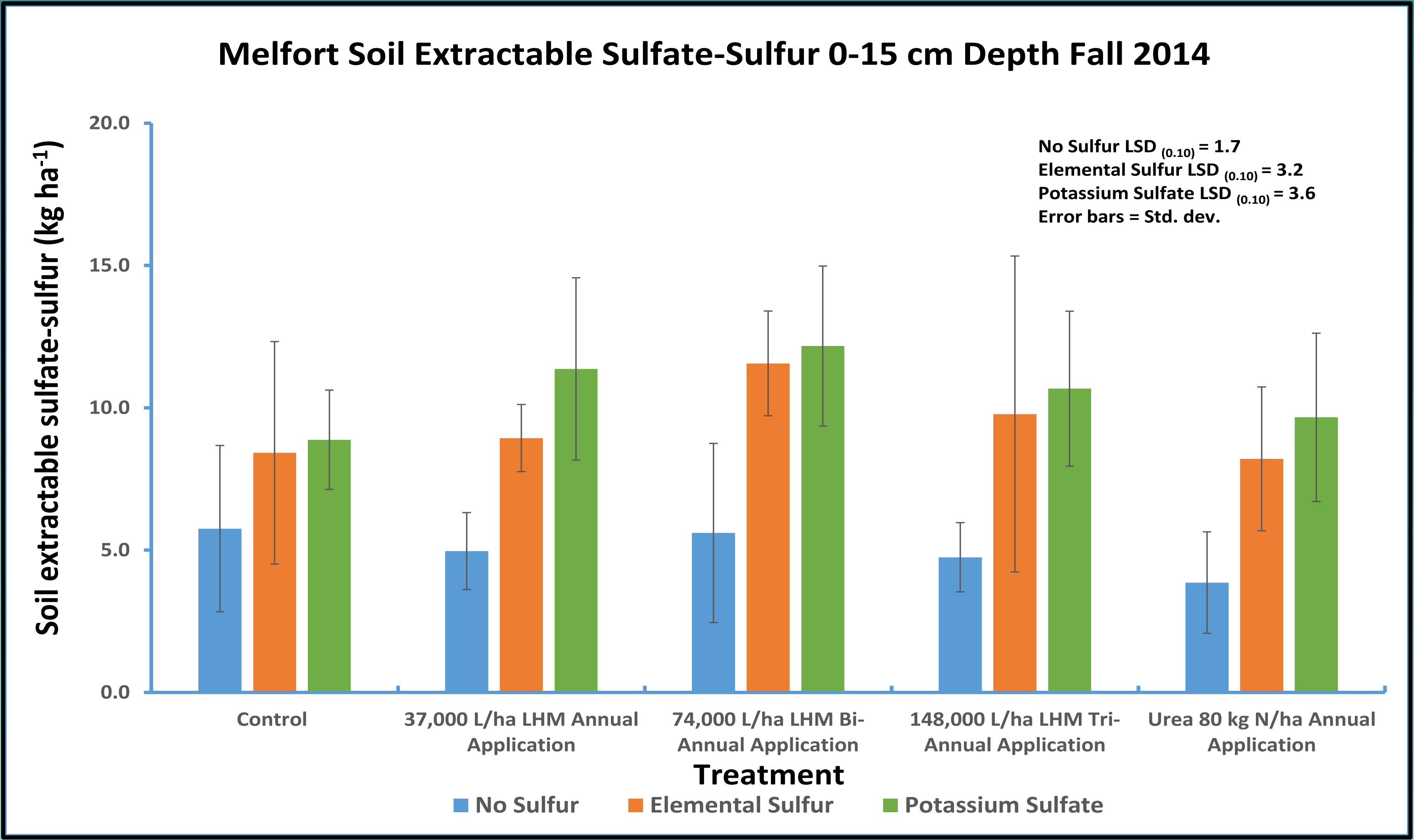
- Buildup of NO_3-N in the urea treatment at 60-90 cm depth, reflecting unused N by canola crop during 2014 growing season.



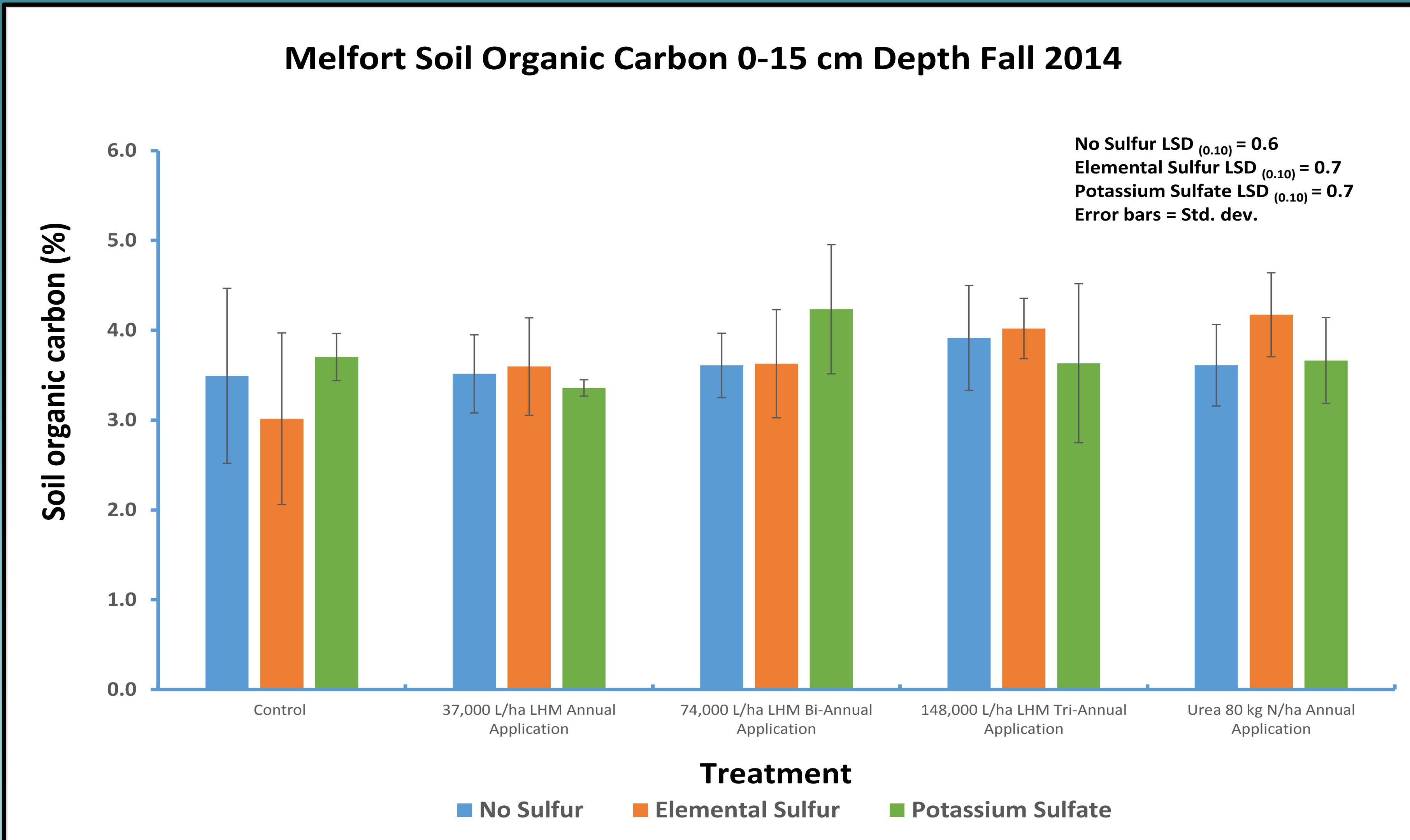
- No excess buildup in soil NO_3-N in the 60-120 cm depth in the LHM treated plots.
- However, migration of N in urea (no S added) fertilized plots, due to unused N over 2014 year by crop.



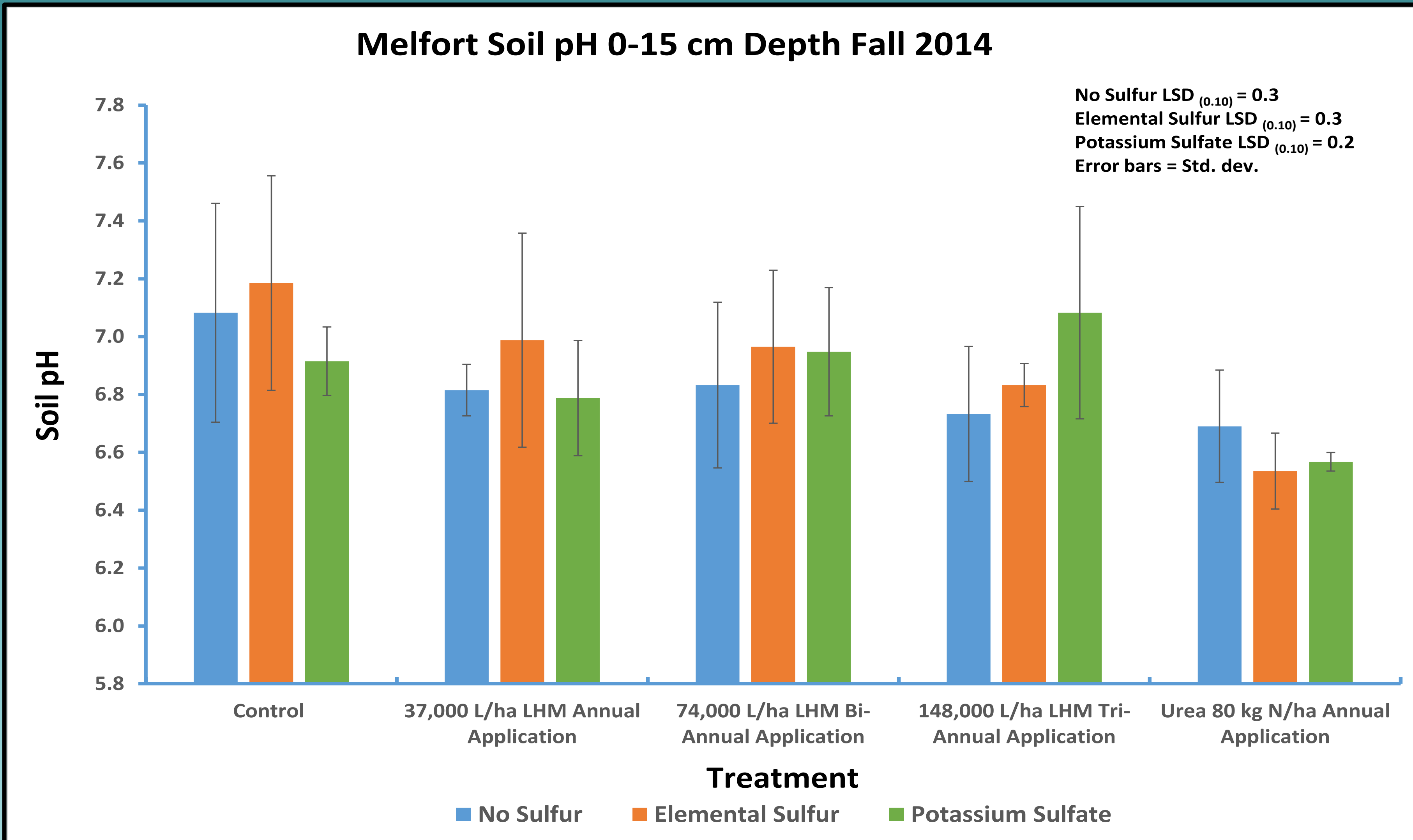
- No excess buildup in soil MK-P by end of 2014.



- S amended treatment plots, as expected were observed to have more SO_4-S in the surface 0-15 cm depth, compared to: non-S amended control, LHM and urea treatment plots.



- After 15 years of LHM application, no significant effect on SOC. Little solid material in LHM (> 90 % water), therefore little OM being added directly to soil.



- Application of LHM had no effect on soil P in upper 0-15 cm depth, compared to non-amended control plots.

Melfort 1999-2014

- Annual application of LHM at the 37,000 L ha^{-1} (3300 gpa) rate annually maximized crop yields, compared to unfertilized control plots.
  - Application of higher rates of LHM every 2nd year 74,000 L ha^{-1} (6600 gpa) and every 3rd year 148,000 L ha^{-1} (9900 gpa) did have carryover effects into subsequent years, however, were not as effective as the annual rate.
- No excessive buildup of soil NO_3-N or P. No evidence of migration of NO_3-N and P to deeper depths.
  - Application of LHM at the agronomic rates utilized in the 1999-2014 trials did not result in nutrient loading.
- Application of LHM with the proper balance of nutrients promotes carbon sequestration in the soil, does not impact soil and environmental quality and aids in improving SOM.
- Limited impact on soil pH and no evidence of salt accumulation.

Conclusion

According to results of the LHM and SCM studies:

LHM and SCM with ***balanced nutrient content*** <u>applied at rates that match crop demand</u> over time **maximizes crop production** and will ***avoid soil nutrient loading and migration issues***.

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